Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

UAV–LiDAR and spaceborne remote sensing for site survey and habitat condition monitoring in the Beetaloo

Long Project Title	UAV–LiDAR and spaceborne remote sensing for site survey and habitat condition monitoring in the Beetaloo
GISERA Project Number	B.9
Start Date	01/08/2023
End Date	20/12/2024
Project Leader	Shaun Levick

GISERA State/Territory

- ☐ Queensland
- ☐ New South Wales
- ☒ **Northern Territory**
- ☐ South Australia
- ☐ Western Australia
- ☐ Victoria
- ☐ National scale project

Basin(s)

- ☐ Adavale
- ☐ Amadeus
- ☒ **Beetaloo**
- ☐ Canning
- ☐ Western Australia
- ☐ Carnarvon
- ☐ Clarence-Morton
- ☐ Cooper
- ☐ Eromanga
- ☐ Galilee
- ☐ Gippsland
- ☐ Gloucester
- ☐ Gunnedah
- ☐ Maryborough
- ☐ McArthur
- ☐ North Bowen
- ☐ Otway
- ☐ Perth
- ☐ South Nicholson
- ☐ Surat
- ☐ Other (please specify)

GISERA Research Program

- ☐ Water Research
- ☐ Health Research
- ☒ **Biodiversity Research**
- ☐ Social & Economic Research
- ☐ Greenhouse Gas Research
- ☐ Agriculture Research
- ☐ Land and Infrastructure Management Research
- ☐ Other (please specify)

1. Project Summary

The community has concerns about the long-term impacts of gas development on the biodiversity of the Beetaloo region. They need reassurance that potential impacts are being mitigated and that any effects of resource development can be detected and managed. Effective approaches to monitoring the condition of ecosystems that support biodiversity and how they may be changing will be important in providing this reassurance. The recently completed Strategic Regional Environmental and Baseline Assessment (SREBA) for the Beetaloo Sub-basin, which collected baseline data to provide a reference point for ongoing monitoring, has highlighted the need for ongoing monitoring, stating that monitoring "is essential for testing whether the previous assessment of risks was accurate, that mitigation measures and regulatory controls are effective, and to trigger and inform appropriate corrective measures if unacceptable impacts occur."

For terrestrial ecosystems, reliable estimates of habitat change are critical for monitoring the effects of resource development and minimising adverse consequences for biodiversity. However, monitoring change in habitat and attributing causality to specific drivers is extremely challenging in heterogeneous ecosystems. Field surveys are spatially and temporally limited, and the sensitivity of satellite remote sensing to subtle disturbances, and those that compound through time, is still poorly understood. Without accurate and scalable monitoring tools in place, landowners, regulators, and other stakeholders lack confidence that the natural and important characteristics of the ecosystem are preserved.

Recent rapid advances in UAV-LiDAR technology now enable the three-dimensional (3D) reconstruction of landscapes and vegetation in fine detail, over large spatial areas. This technology provides a bridge between what can be collected in the field, and what can be estimated from space. It provides a robust snapshot of ecosystem state at a particular point in time, that can be used for calibrating and validating satellite remote sensing products. We will use high-precision UAV-LiDAR remote sensing to map key areas of interest at repeated time intervals to assess change in habitat structure through time. We will use these 3D temporal datasets to test the sensitivity of different satellite sensors for detecting patterns of system dynamics and to develop a scalable method for monitoring habitat change over larger spatial areas. This combination of high-quality 3D data at local scales and well calibrated satellite data over larger scales will help ensure that mitigation measures and regulatory controls achieve their objectives.

2. Project description

Introduction

The development of an onshore gas industry in the Beetaloo Sub-basin has potential to impact on terrestrial biodiversity, ecosystem function and landscape amenity. Community concerns about these impacts were noted in *The Final Report of the Inquiry into Hydraulic Fracturing in the Northern Territory* (2018) (Chapter 8). The Geological and Bioregional Assessment for the Beetaloo GBA region (Geological and Bioregional Assessments Program, 2021) also noted that the process of habitat degradation, fragmentation and loss as a result of a number of impact pathways has the potential to impact on a broad range of environmental values (see GBA website). The assessment of the Beetaloo GBA region found that these potential impacts could be mitigated, but also emphasised the importance of ongoing monitoring. The recently completed Strategic Regional Environmental and Baseline Assessment (SREBA) for the Beetaloo Sub-basin collected extensive new data on terrestrial ecosystems. One of the purposes of the SREBA is to provide baseline data that serves as a reference point for ongoing monitoring. The SREBA studies also reiterated the importance of ongoing monitoring.

Monitoring trends in habitat condition and attributing causality to specific drivers is extremely challenging in heterogenous ecosystems. Traditional monitoring approaches rely on field-based estimates of habitat condition, but these approaches are necessarily limited in their spatial and temporal representation of landscapes. Field-based measures of habitat condition focus on a small number of habitat metrics that are feasible to measure on the ground, but which may not holistically capture habitat status. Remote sensing technology offers solutions for habitat monitoring that are spatially continuous and systematically collected through time. Such measurement approaches are appealing from a monitoring perspective as spatio-temporal trends in data can be interrogated to understand natural system dynamics and identify deviations from expected patterns. However, the trade-off for most satellite sensors that provide wall-to-wall mapping at regular time intervals (e.g. Landsat and Sentinel missions) is that they acquire information of limited dimensionality and at resolutions coarser than individual plant canopies. To maximise the utility of these sensors for monitoring habitat condition and dynamics, it is critical to calibrate the reflectance and backscatter signals with comprehensive on-ground data.

Most remote sensing research in the field of habitat condition monitoring has focused on multi-spectral reflectance, however in dynamic tree-grass ecosystems and in landscapes with prominent background soil reflectance, spectral indicators of habitat structural and ecophysiological state (like water status) saturate rapidly in the multi-spectral domain. Here, we propose testing a purely structural approach to this challenge by using Synthetic Aperture Radar (SAR) satellites to assess subtle changes in structural characteristics that are associated with habitat condition. We will test the sensitivity of Synthetic Aperture Radar (SAR) imagery to spatio-temporal variation in habitat structural properties, using high-quality UAV-based LiDAR data for calibration and validation.

Prior Research

The Beetaloo Sub-region has been a focus of environmental research since 2018. The major projects undertaken in the period 2018-2023 that are relevant to the current project are summarised below.

The Geological and Bioregional Assessment (GBA) of the Beetaloo Sub-basin produced a series of reports covering the natural and social landscape of the region. It also provided a full impact assessment and developed causal pathways that linked activities from an onshore gas industry and identified how these created stressors that impacted on values to be protected including threatened species and other aspects of biodiversity (refer to Beetaloo GBA region synthesis).

The GBA found that most potential impact pathways are related to surface disturbance such as civil construction and decommissioning and rehabilitation. The pathways of concern connect these activities with the protected matters, protected fauna and terrestrial vegetation endpoints, reflecting the potential impact of surface disturbance. The assessment determined that this potential impact can be minimised or mitigated by existing management controls (Huddlestone-Holmes 2020).

The causal network for the Beetaloo identifies the points along a pathway where monitoring would be most useful. Results from the impact assessment informed four broad monitoring objectives: (i) estimating baseline and trend, (ii) comparing areas of potential impact with areas where no changes occur (control sites), (iii) monitoring compliance with, and effectiveness of, mitigation strategies, and (iv) monitoring to validate and refine the causal network.

The Strategic Regional Environmental and Baseline Assessment (SREBA) for the Beetaloo Sub-basin was undertaken following the recommendations of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018).The SREBA addressed several key topics across the Beetaloo including water quality and quantity, aquatic ecosystems, terrestrial ecosystems, greenhouse gases, human health and social, cultural and economic studies. Regional vegetation mapping and systematic flora (1,818 taxa) and fauna (354 vertebrate species) surveys have greatly increased knowledge of the terrestrial ecosystems in the Beetaloo region. The main terrestrial biodiversity values within the study area were stated to be: (a) Sites of Conservation Significance (Mataranka Thermal Pools and Lake Woods/Longreach Waterhole), (b) high value vegetation types, and (c) important habitat for waterbirds and threatened species (Department of Environment Parks and Water Security 2022).

The final report from the SREBA concluded that the results from the SREBA can be used to inform the development of a regional monitoring framework for the Beetaloo Sub-region (Department of Environment Parks and Water Security 2022). The current project proposal has been developed to partly fill this important gap.

The GISERA program in the Northern Territory has funded several important projects, at least two of which are relevant to the current proposal. The GISERA *Putting land management knowledge into practice project* (Huth et al. *in prep*) explored the use of high resolution 'digital twin' created from photogrammetry to evaluate the design and placement of gas infrastructure, protect surface water and vegetation, and reduce erosion, soil damage and dust. The GISERA *Beetaloo biodiversity project* (Pavey et al. *in prep*.) assessed the impacts to biodiversity of roads and other infrastructure, and of habitat fragmentation in the Beetaloo Sub-region focussed on the area east of Daly Waters where most development is likely to occur. The study examined vegetation fragmentation and connectivity using high-resolution (10 m) surfaces modelled using Sentinel-2 composite multi-spectral images from the dry season of 2021 (July-September). The study focussed on vegetation with a woody cover fraction of > 20 % and a height of > 2 m. Pixel-based methods for assessing fragmentation and connectivity were applied to four regions each of 50 km by 50 km. The study showed that indicators of fragmentation (FAD; Foreground Area Density) and connectivity (MSPA; Morphological Spatial Pattern Analysis), although designed for forest ecosystems, can also be applied to savanna and associated vegetation in northern Australia including the Beetaloo Sub-region.

The study also assessed patch mosaics in areas of bullwaddy (*Macropteranthes kekwickii*) and lancewood (*Acacia shirleyi*) vegetation that potentially support the highest concentrations of species 'at risk' from linear corridors. Sampling was stratified across three patch categories: large, medium, and small. Floristic composition and vegetation structure differed according to patch size, and results suggest that the species-rich small bullwaddy stands may be persisting as low flammability islands in the landscape matrix of highly flammable savanna. In contrast, lancewood is currently absent from portions of the landscape where fire is frequent because, compared to bullwaddy, it is fire-prone, and it is very sensitive to fire interval due to its long juvenile period and low resistance to fire in adult trees. The small patches of bullwaddy may therefore be a sign that fire is presently too frequent in this landscape and lancewood stands are being lost. Overall, the study found the small patches dominated by bullwaddy to need management focus. These results suggest that ongoing monitoring should focus on areas of bullwaddy.

Three-dimensional structure is a fundamental physical element of habitat and has long been identified as a key determinant of biological diversity, particularly in woodland ecosystems (Macarthur and Macarthur 1961). LiDAR can supply detailed information about the vertical structure of vegetation elements and their spatial variability, and thus its use in habitat assessment has gained rapid traction since its emergence in ecology (Lefsky et al. 2002). Most studies utilising LiDAR for assessing habitat focus on deriving a spatial model of one or more elements of vegetation vertical or horizontal structure, and then apply these models for predicting habitat suitability for a specific organism based on known habitat requirements (Hill and Hinsley 2015). Very few studies have tried to explore the upscaling of LiDAR to SAR in the context of biodiversity monitoring, but there is evidence from temperate forests that this approach has merit (Bae et al. 2019).

Need & Scope

This project will work to extend a feasibility study conducted as part of the GBA program to use remote sensing technology to monitor the condition of habitat in the Beetaloo region. It will leverage the extensive field data collection that has been undertaken by NTG and other partners under SREBA, as well as new insights gained into fragmentation patterns from a recent GISERA project (Pavey et al. *in prep*). The scientific value spans both applied and empirical research, as there is growing momentum internationally and nationally for Earth Observation science to inform the monitoring of Essential Biodiversity Variables (EBVs) and the United Nation's System of Environmental Economic Accounting (SEEA). However fundamental research into new sensor technologies, their sensitivities to different magnitudes of change, and their scalability, needs to be undertaken to provide confidence in these assessments. Overcoming these gaps in knowledge is key to advancing routine operational monitoring of habitat condition over large and remote landscapes, and to verify effectiveness of mitigation methods.

Petroleum interest holders are required to describe the existing environment that may be affected by proposed activities in their Environmental Management Plans (see EMP Guidelines). They must also have a monitoring program that allows for auditing of the environmental performance of the activity. Robust, repeatable, and easily deployable technologies that allow habitat condition to be reliably measured and monitored will be highly valuable in achieving these requirements. Demonstrating the potential for high resolution UAV-based LiDAR, and spaceborne technologies, will enable their application to be properly considered.

Objective

The primary objective of this project is to develop a scalable approach for monitoring the structural condition of vegetation. The project will focus on two key areas of interest: i) trends in vegetation status in critical habitat (e.g., ground water dependant ecosystems, threatened species habitat, bullwaddy patches); and ii) trajectories of change along newly established edges (e.g., perimeter of well-pads and access roads).

The study will demonstrate the application of high-resolution LiDAR to study site characterisation – providing quantitative assessment of topography, aboveground biomass, and structural diversity. In addition to providing local scale assessment around well pads or other infrastructure, it will test the potential for upscaling to larger areas via satellite based remote sensing platforms. These explorations will lay the foundation for monitoring longer term trends and identifying the underlying drivers - including structural changes due to weed establishment, altered fire regimes, changes to overland flow/run off, and altered grazing patterns due to infrastructure construction.

Methodology

The study objective will be approached through the integration of time-series UAV-LiDAR and spaceborne synthetic aperture radar (SAR) remote sensing. The collection of high-resolution UAV-LiDAR data at repeat time intervals will enable the reconstruction of habitat 3D structure through time at sub-canopy scales. These rich 3D renderings will be used to train and validate SAR imagery for regional upscaling of vegetation canopy structural condition assessment.

The study design will consider two settings in which changes are anticipated to occur – undisturbed habitat subject to seasonal changes in plant area density (PAD), and habitat surrounding sites that have been cleared for development. At each of these sites, UAV-LiDAR will be collected at approximately 3-monthly intervals to build a time series of structural change that can help interpret signals observed from satellite sensors and quantify uncertainty when upscaling monitoring to larger areas.

The focus of the UAV-LiDAR collection is the creation of vegetation structural time-series, so we will prioritise repeat measurements over geographic coverage (which is the domain of the airborne and satellite upscaling component). We anticipate that we will be able to capture a minimum of six sites (100 ha each) with the high-precision UAV-LiDAR system at five different time points over the course of the project. The specific location of these six sites will be determined after consultation with the Technical Reference Group, however due to logistical and ecological considerations it is likely that these will be in the vicinity of the Carpentaria Highway. We will aim to ensure coverage of lancewood, bullwady, and riparian patches. At least two of the study sites will be located within the areal coverage of existing airborne LiDAR acquired by project partners.

Task 1. UAV-LiDAR data collection & raw processing

UAV-LiDAR data will be collected over the selected study sites using a large drone platform (Acecore NOA airframe) and a survey grade LiDAR sensor (Riegl VUX-120). The Acecore NOA has a maximum take-off weight of 36 kg and an endurance of 30 minutes under typical conditions in the Northern Territory. The large size of the drone increases stability in the air, allowing for high precision ranging estimates. The VUX-120 sensor has an accuracy and precision of 10 and 5 mm, respectively, and is unique among UAV sensors in that it emits the laser pulses in a forward-nadir-backwards (FNB) scan pattern, which increases returns from vertical surfaces (such as riverbanks and tree trunks). The UAV-LiDAR system can survey a 1 X 1 km area of interest in a single 30-minute flight. When flown at 120 m above ground level (maximum height set by CASA) and at 8 ms^{-1} this equates to a sampling density of 1000 points per m^2.

The trajectory data from the UAV surveying will be coupled with GNSS base-station data and processed through Trimble’s POSPAC UAV module to provide corrected trajectory information for each UAV flight. These corrected trajectories will be used to process the raw LiDAR data flightlines with Riegl’s RiProcess software, using the RiPrecision flightline adjustment module. Geolocated point cloud will be exported in .las format, and a final strip alignment will be conducted using Bayes Strip Align. The processed flightline data will be gridded into 1 ha tiles and passed through a series of LASTools batch scripts for initial ground classification and vegetation height normalization.

Task 2. 3D point cloud analysis and SAR calibration

Individual tree segmentation and volumetric reconstruction will be performed using the open-source RayCloudTools, developed by CSIRO's Data61 (Lowe and Stepanas 2021). The outputs from this segmentation step will then be further refined into grass, leaf, wood, and coarse woody debris classifications using a PointNet++ Deep Learning model based upon the FSCT algorithm (Krisanski et al. 2021) running on CSIRO's High-Performance Computing resources (*Petrichor*). These classified point clouds will be used to: i) identify key vegetation types; ii) distinguish between healthy, stressed, and dead woody vegetation; iii) identify patches of habitat with high biodiversity potential. Field data collected under SREBA and previous GISERA projects will be used for training the vegetation type classification, and for identifying a suite of ecologically meaningful structural metrics that can be mapped from the LiDAR outputs.

Synthetic Aperture Radar (SAR) imagery (initially Sentinel-1) for each study site will be downloaded for the time periods buffering each of the UAV-LiDAR flights. Relationships between SAR backscatter intensity and coherence will be tested at each time interval to assess how the relationship between SAR signal and 3D structure changes through time. Raw SAR processing and interferometric baseline analysis will be conducted in the Sentinel Application Platform (SNAP) and ENVI SARscape (Castellazzi et al. 2023). These findings will be used to develop local calibration rules for SAR image processing to be applied across longer time intervals and larger spatial scales in Task 3.

Task 3. Upscaling to larger areas with spaceborne SAR

The upscaling component of this study will focus initially on expanding Sentinel-1 SAR results to wider areas within the Beetaloo Sub-basin. Sentinel-1 uses a C-band wavelength which is sensitive to vegetation elements of approximately 5-7 cm, meaning that is it well suited to the characterization of branches and leaves within vegetation canopies (Philipp and Levick 2020). If the launch of NISAR (scheduled for launch in January 2024) is successful, we will incorporate the L-band data from this mission into the study. The longer wavelength of L-band sensors (12-15 cm) is better suited to aboveground biomass mapping with its sensitivity to larger branches and trunks of trees (Silva et al. 2021).

Airborne LiDAR that has already been acquired by project partners (1,500 km^2 at 16 points/m^2) will be used to validate the structural metric modlleing from the UAV-LiDAR and SAR datasets across larger landscapes.

Geospatial modelling relating SAR backscatter intensity and coherence properties to LiDAR structure will be conducted in the Python programming language on Open Data Cube infrastructure (CSIRO EASI

Hub). The Deep Learning model that we develop will most likely be based upon PointNet++, running through PyTorch and CUDA (Kalinicheva et al. 2022).

Task 4: Project reporting

The results of the work will be brought together into a detailed final report following the standard GISERA report template. It is anticipated that the findings will be published in a peer-reviewed journal, such as *Remote Sensing of Environment* or *Remote Sensing in Ecology and Conservation*.

Data collected through the project will be made publicly available and shared with the NT government royalty free for future use. Certain access restrictions may apply however for datasets that could contain sensitive information about commercial stakeholder activities, and the release of these datasets will be discussed on a case-by-case basis with the stakeholder.

Task 5: Communicate project objectives, progress and findings to stakeholders

The project lead and team will liaise closely with GISERA's Communications team and will participate in a range of communication activities including providing information on the GISERA website, presenting to government and industry at a Knowledge Transfer Session once the project is complete, presenting at research conferences, and assisting in the preparation of fact sheets and other materials as required and sanctioned. The team will also establish and engage with a technical refence group (details in section below).

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Shaun Levick	60 days	LiDAR remote sensing	20 years	CSIRO
Steph Johnson	55 days	Spatial analysis	5 years	CSIRO
Chris Pavey	45 days	Ecology	30 years	CSIRO
Stephen Stewart	65 days	Spatial analysis	7 years	CSIRO
Pascal Castellazzi	40 days	SAR remote sensing	7 years	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
N/A				

Technical Reference Group

The project will establish a Technical Reference Group (TRG) aimed at seeking peer-to-peer technical advice on contextual matters and to discuss research needs as well as outputs as the project progresses. The TRG will include the project leader and a group of different stakeholders as appropriate including the following:

- Senior researcher from the Flora and Fauna Division, Department of Environment, Parks and Water Security, Northern Territory Government.
- Representative from Petroleum Operations, Environment Division, Department of Environment, Parks and Water Security, Northern Territory Government.
- Representative from Drone Operations and Technology Solutions Group, Supervising Scientist Branch, Heritage, Reef and Oceans Division, Department of Climate Change, Energy, the Environment and Water.
- A spatial scientist from the Rangelands group of the Department of Environment, Parks and Water Security, Northern Territory Government.
- Senior researcher within CSIRO with expertise in remote sensing.
- One or more technical experts from the gas industry.

Budget Summary

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
GISERA	$0	$185,893	$177,700	$0	80%	$363,593
- Federal Government	$0	$125,478	$119,948	$0	54%	$245,425
- NT Government	$0	$48,797	$46,646	$0	21%	$95,443
- Santos	$0	$11,618	$11,106	$0	5%	$22,725
Total Cash Contributions	**$0**	**$185,893**	**$177,700**	**$0**	**80%**	**$363,593**

Source of In-Kind Contribution	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
CSIRO	$0	$46,473	$44,425	$0	20%	$90,898
Total In-Kind Contribution	**$0**	**$46,473**	**$44,425**	**$0**	**20%**	**$90,898**

TOTAL PROJECT BUDGET	2022/23	2023/24	2024/25	2025/26	-	TOTAL
All contributions	$0	$232,366	$222,125	$0	-	$454,491
TOTAL PROJECT BUDGET	**$0**	**$232,366**	**$222,125**	**$0**	**-**	**$454,491**

4. Communications Plan

Stakeholder	Objective	Channel (e.g. meetings/media/factsheets)	Timeframe (Before, during at completion)
Regional community stakeholders, including landholders and traditional owners, and the wider public	To communicate project objectives, key messages and findings from the research	A fact sheet at commencement of the project, which explains in plain English the objective of the project.	At project commencement
		Project progress reported on the GISERA website to ensure transparency for all stakeholders including regional communities.	Ongoing
		Public release of final reports. Plain English fact sheet summarising the outcomes of the research.	At project completion
		Preparation of an article for the GISERA newsletter and other media outlets as advised by GISERA's communication team.	At project completion
Gas Industry & Government	To communicate the final results of the project. Gas industry potentially adopts methods for improving monitoring of habitat condition.	Fact sheet that explains the objective of the project.	At project commencement
		Project progress reporting (on GISERA website)	Ongoing
		Final project report and fact sheet.	At project completion
		Presentation of findings at joint gas industry/government Knowledge Transfer Session	At project completion
Scientific Community	Provide scientific insight into scaling relationships between UAV-LiDAR and spaceborne SAR for habitat condition monitoring.	Peer-reviewed scientific publication. Dataset(s) available through CSIRO's data repository.	After completion of project

In addition to project specific communications activities, CSIRO's GISERA has a broader communications strategy. This strategy incorporates activities such as webinars, roadshows, newsletters and development of other communication products.

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
UAV-LiDAR data collection & raw processing	Datasets in the form of geolocated point clouds enabling 3D representation of vegetation structure.	Scientific understanding of baseline habitat structural attributes across selected locations in the Beetaloo Sub-region.	Government regulators have improved scientific understanding and improved scientific rigour when assessing the effects of an unconventional gas industry on the natural environment. The unconventional gas industry has improved knowledge of the effects of their activities on the natural environment.	Improved community understanding of the impacts of unconventional gas development on the natural environment. Improved capacity for regulators to monitor the impacts of an unconventional gas industry on the natural environment. Application of leading-edge technology from earth observation science (both LiDAR and RADAR) into environmental monitoring with the result of increased scientific robustness and rigour.
3D point cloud analysis and SAR calibration	Datasets in the form of LiDAR voxels, volumetric reconstructions of individual trees and branches, and height and canopy cover structural metrics.			
Upscaling to larger areas with spaceborne SAR	A Deep Learning model that relates metrics of habitat structure and dynamics from voxelised LiDAR point clouds to signals observable from Sentinel-1 SAR imagery.	Scientific knowledge and proven processes that will enable the long-term monitoring of habitat condition in the Beetaloo Sub-region.	Availability of cost-effective approaches to long-term monitoring of the impacts of unconventional gas development on the natural environment.	
Stakeholder engagement	Information on the GISERA website. Presentation to government and industry at a Knowledge Transfer Session once the project is complete.	The community is informed about scientific activities and findings relevant to ongoing monitoring of the impacts of unconventional gas	Greater trust between the community, industry, government, and CSIRO.	

	Presentations at research and community workshops/open days/road shows. Fact sheets. Media appearances.	development on the natural environment.		

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	UAV-LiDAR data collection	Steph Johnson	1 August 2023	30 June 2024	-
Task 2	3D point cloud analysis and SAR calibration	Shaun Levick	1 September 2023	30 June 2024	Task 1
Task 3	Upscaling to larger areas with spaceborne SAR	Stephen Stewart	1 July 2024	30 November 2024	Tasks 1 and 2
Task 4	Project reporting	Shaun Levick	1 August 2023	30 November 2024	Tasks 1, 2 and 3.
Task 5	Communicate findings to stakeholders	Shaun Levick	1 August 2023	20 December 2024	None.

Task description

Task 1: UAV-LiDAR data collection and raw processing

OVERALL TIMEFRAME: 1 August 2023 – 30 June 2024

BACKGROUND**:** UAV-based LiDAR offers a tremendous opportunity to develop a high quality and quantity monitoring program for change in habitat structural conditions of any ecosystems in response to disturbance. There is a clear opportunity to harness this technology to improve the monitoring framework for the Beetaloo Sub-region once an unconventional gas industry is established. The main step in the use of UAV-LiDAR is to obtain the high-resolution point clouds that are required to provide a basis for assessing structural change and for calibrating spaceborne imagery. This task focuses on selecting suitable sites to meet the project objectives, obtaining flight plan permissions, and conducting the UAV surveys to collect the data.

TASK OBJECTIVES**:** i) Acquire high-resolution UAV-LiDAR data over select study sites at key times in the seasonal cycle; ii) Process IMU trajectory, GNSS base-station, and UAV-LiDAR flight data.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Analysis ready datasets in the form of geolocated point clouds (.las format version 1.4).

Task 2: 3D point cloud analysis and SAR calibration

OVERALL TIMEFRAME: 1 September 2023 – 30 June 2024

BACKGROUND: Changes in habitat structure for each study site will be assessed from voxelised versions of the time-series point cloud data collected in Task 1. Cloud-to-cloud distancing will be used to quantify the degree of change occurring in different components of the vegetation canopy through time. These voxelised representations of 3D structure and structural change will be used to test the sensitivity of Sentinel-1 C-band SAR for habitat structural condition monitoring. Time-series of Sentinel-1 backscatter intensity and coherence will be developed for each site for modelling against the voxel outputs.

TASK OBJECTIVES: i) Develop voxelised representations of structural change; ii) download and prepare Sentinel-1 data for analysis; iii) complete raw processing of Sentinel-1 data; and iv) define a suite of UAV-LiDAR metrics that have ecological relevance to key species of interest in the region.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Classified and segmented LiDAR voxels (.ply format). Volumetric reconstructions of individual trees and branches (.ply format). Height and canopy cover structural metrics.

Task 3: Upscaling to larger areas with spaceborne SAR

OVERALL TIMEFRAME: 1 July 2024 – 30 November 2024

BACKGROUND: Cost-effective monitoring of habitat condition over large areas requires a satellite-based solution, with systematic wall-to-wall mapping at regular repeat time intervals. This task will use the outputs from Tasks 1 & 2 to develop a Deep Learning model that relates metrics of habitat structure and dynamics from voxelised LiDAR point clouds to signals observable from Sentinel-1 SAR imagery. Reliability across larger spatial area will be validated with existing airborne LiDAR datasets.

TASK OBJECTIVES: i) Develop a Deep Learning model for relating UAV-LiDAR characterisation of 3D structure and change to Sentinel-1 SAR image properties; ii) publish workflow and write up final report.

TASK OUTPUTS AND SPECIFIC DELIVERABLES**:** i) Deep Learning model; and ii) Jupyter Notebook with detailing processing workflow.

Task 4: Project Reporting

OVERALL TIMEFRAME: 1 August 2023 – 30 November 2024

BACKGROUND: Information from this project is to be made publicly available after completion of standard CSIRO publication and review processes.

TASK OBJECTIVES: To ensure that the information generated by this project is documented and published after thorough CSIRO internal review.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

1. Preparation of a final report outlining the scope, methodology and findings;
2. Following CSIRO ePublish review, the report will be submitted to the GISERA Director for final approval; and
3. Provide 6 monthly progress updates to GISERA office.

Task 5: Communicate project objectives, progress and findings to stakeholders

OVERALL TIMEFRAME: Full duration of project

BACKGROUND: Communication of GISERA research is an important component of all projects. The dissemination of project objectives, key findings and deliverables to relevant and diverse audiences allows discourse and decision making within and across multiple stakeholder groups.

TASK OBJECTIVES: Communicate findings to stakeholders through meetings, Knowledge Transfer Session, fact sheets, project reports and journal articles, in collaboration with GISERA Communication officers.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communicate results to GISERA stakeholders according to standard GISERA project procedures, which will include but is not limited to the activities listed below.

1. Engagement with an established technical reference group.
2. Two project fact sheets: one developed at the commencement of the project, and another that will include peer-reviewed results and implications at completion of the project. Both will be hosted on the GISERA website.
3. Project reporting.
4. Knowledge Transfer session with Government/Gas Industry.
5. Preparation of an article for the GISERA newsletter and other media outlets as advised by GISERA's communication team.
6. Peer-reviewed scientific manuscript ready for submission to relevant journal.

Project Gantt Chart

		2023/24											2024/25					
Task	**Task Description**	**Aug 23**	**Sep 23**	**Oct 23**	**Nov 23**	**Dec 23**	**Jan 24**	**Feb 24**	**Mar 24**	**Apr 24**	**May 24**	**Jun 24**	**Jul 24**	**Aug 24**	**Sep 24**	**Oct 24**	**Nov 24**	**Dec 24**
1	UAV-LiDAR data collection & raw processing	■	■	■	■	■	■	■	■	■	■	■						
2	3D point cloud analysis and SAR calibration		■	■	■	■	■	■	■	■	■	■						
3	Upscaling to larger areas with spaceborne SAR												■	■	■	■	■	
4	Project reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	Communicate findings to stakeholders	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

7. Budget Summary

Expenditure	2022/23	2023/24	2024/25	2025/26	Total
Labour	$0	$177,366	$197,125	$0	$374,491
Operating	$0	$55,000	$25,000	$0	$80,000
Subcontractors	$0	$0	$0	$0	$0
Total Expenditure	**$0**	**$232,366**	**$222,125**	**$0**	**$454,491**

Expenditure per task	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$0	$87,892	$0	$0	$87,892
Task 2	$0	$144,474	$0	$0	$144,474
Task 3	$0	$0	$159,617	$0	$159,617
Task 4	$0	$0	$43,888	$0	$43,888
Task 5	$0	$0	$18,620	$0	$18,620
Total Expenditure	**$0**	**$232,366**	**$222,125**	**$0**	**$454,491**

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (54%)	$0	$125,478	$119,948	$0	$245,425
NT Govt (21%)	$0	$48,797	$46,646	$0	$95,443
Santos (5%)	$0	$11,618	$11,106	$0	$22,725
Total Cash Contributions	**$0**	**$185,893**	**$177,700**	**$0**	**$363,593**

In-Kind Contributions	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (20%)	$0	$46,473	$44,425	$0	$90,898
Total In-Kind Contributions	**$0**	**$46,473**	**$44,425**	**$0**	**$90,898**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$245,425	54%
NT Government investment	$95,443	21%
Santos investment	$22,725	5%
CSIRO investment	$90,898	20%
Total Expenditure	**$454,491**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	UAV-LiDAR data collection & raw processing	GISERA	Aug-23	Jun-24	2023/24	$70,314
Task 2	2.1	3D point cloud analysis and SAR calibration	GISERA	Sep-23	Jun-24	2023/24	$115,579
Task 3	3.1	Upscaling to larger areas with spaceborne SAR	GISERA	Jul-24	Nov-24	2024/25	$127,694
Task 4	4.1	Project reporting	GISERA	Aug-23	Nov-24	2024/25	$35,110
Task 5	5.1	Communicate findings to stakeholders	GISERA	Aug-23	Dec-24	2024/25	$14,896

8. Intellectual Property and Confidentiality

Background IP (clause 11.1, 11.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
				$
				$
Ownership of Non-Derivative IP (clause 12.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project Results are not confidential.			
Additional Commercialisation requirements (clause 13.1)	Not Applicable			
Distribution of Commercialisation Income (clause 13.4)	Not applicable			
Commercialisation Interest (clause 13.1)	**Party**		**Commercialisation Interest**	
	CSIRO		N/A	
	Santos		N/A	

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