Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Risks of fragmentation from CSG activities for species and ecosystems in the Pilliga Forest

Long Project Title	Remote sensing and threatened species surveys to better understand risks of forest fragmentation from the Narrabri Gas Project
GISERA Project Number	B.8
Start Date	10/01/2023
End Date	30/06/2024
Project Leader	Chris Pavey

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

Development of the Narrabri Gas Project (hereafter, NGP), with up to 850 gas wells and 1,000 ha of vegetation clearance, will increase habitat fragmentation in a portion of an ecosystem (State of New South Wales through the Independent Planning Commission 2020), the Pilliga Forest, that at ~535 000 ha constitutes the single largest area of inland plains forest in Australia. The local community has raised specific concerns about potential negative environmental impacts from the project including fragmentation impacts resulting in detrimental edge effects, vegetation clearance, declines of 'at risk' species, and loss of ecosystem functioning. However, development of the gas industry is taking place in a region that is already fragmented from other land uses particularly timber harvesting for forestry. Therefore, scientific understanding is needed to determine how fragmentation resulting from the NGP will add to the existing impacts from prior land use fragmentation on biodiversity, especially threatened species persistence, in the Pilliga Forest. To achieve this objective, the current project will: (1) quantify the existing level of fragmentation across landscapes with differing land uses (forestry versus conservation), (2) assess how fragmentation influences the occupancy of sites by threatened plants and animals and mycorrhizal fungi, (3) assess structural attributes of habitat currently occupied by focal threatened species in order to predict whether habitat suitability will be impacted by fragmentation resulting from the NGP, and (4) develop a framework for remote monitoring of habitat condition (including fragmentation and connectivity) during the life of the NGP.

2. Project description

Introduction

The NGP occupies a portion of an ecosystem, the Pilliga Forest, that at ~535 000 ha constitutes the single largest area of inland plains forest and woodland in Australia. Approximately 50% of the area is managed by Forestry Corporation of New South Wales for timber production (Gonsalves et al. 2018), while the remaining areas are managed for conservation by the National Parks and Wildlife Service (much of this area was previously managed for timber production). The area has been important for timber production since the 1800s, especially for the cutting of ironbarks for railway sleepers and logging of cypress (Law et al. 2018).

Much of the Pilliga area was thought to be originally open woodland with a similar plant species composition to today. The dominant tree species were white cypress pine (*Callitris glaucophylla*) and narrow-leaved ironbark (*Eucalyptus crebra*) (Binns and Beckers 2001). However, increasing tree density, particularly of white cypress pine, appears to have resulted from a combination of altered burning regimes, introduction of rabbits and interactions with drought and flood years. The vegetation of the Pilliga is today dominated by dense stands of white cypress pine as well as black cypress pine (*C. endlicheri*), buloke (*Allocasuarina luehmannii*), with *Acacia* spp. and narrow-leaved ironbarks scattered throughout the forest. Silvicultural treatment to maximise tree growth for timber

production has developed a forest with a range of management histories, including logging and thinning of various ages (Gonsalves et al. 2018).

The Pilliga Forest has experienced significant fires in November 1951 (Norris et al. 1991) and November 2006. The 2006 fire burnt over 120,000 ha (Law et al. 2018).

The NGP will take place within a 95,000 ha project area to the south of the town Narrabri. Approximately two-thirds of the project area (62,750 ha) is located within the Pilliga State Forest with the remainder on privately-owned agricultural land to the north of the Pilliga State Forest. Surveys within the project area have identified 807 species of terrestrial plants (691 of which are native), 22 distinct plant communities, and 289 species of terrestrial vertebrates. Of the plants, 10 species were classified as threatened either under the *Threatened Species Conservation Act* of New South Wales (TSC Act) and/or the *Federal Environment Protection and Biodiversity Conservation Act* (EPBC Act). Of the vertebrate animals, 27 species were classified as threatened under the TSC Act and four species were threatened under the EPBC Act. These communities are underpinned by a range of microbial processes that support plant function. For instance, the majority of plant species are completely reliant on mycorrhizas (plant-fungal symbiosis) to survive in nutrient-poor soils (such as those in the Pilliga). Indeed, more than 90% of plant species form mycorrhizal associations (Helgason et al., 2008). These specific associations play a key role in plant function and distribution. Further, almost no work has been done to characterise mycorrhizal fungi of the Pilliga, and the single study that has been conducted on a single sample from the Jack's Creek region revealed a range of novel hypogeous-fruiting ectomycorrhiza occur. These hypogeous species are key food sources for a range of ground dwelling mammals, including threatened species being examined in this study. In this study, mycorrhizal fungal diversity will also be assessed in parallel to plant surveys using a next generation DNA-sequencing based approach.

The Pilliga region is already fragmented through a major road network (including the Newell Highway) and the provision of roads and tracks for forestry activities. The development of the NGP, with up to 850 gas wells on 425 well pads and associated infrastructure, requires clearing of vegetation (up to 1,000 ha) and will increase forest fragmentation. The number of patches in the study area covered by the Environmental Impact Assessment is predicted to increase from 387 to 721.

Forest fragmentation is a major threat to biodiversity worldwide. It is a process that involves both habitat loss and a change in the configuration of the remaining habitat. Habitat fragmentation can lead to changes in the persistence of species. Fragmentation often alters the microenvironment at the edge of the fragment and can result in increased light levels, higher daytime temperatures, higher wind speeds, and lower humidity. Each of these edge effects can have a significant impact on the vitality and composition of the species in the fragment (Primack and Morrison 2013). Species that are sensitive to humidity such as amphibians, some insects, and herbaceous plants may be eliminated from fragments.

Although underappreciated, there is a considerable amount of published research that shows that habitat fragmentation can also have positive effects on biodiversity (Fahrig 2003, 2017; Fahrig *et al.* 2018). These positive effects include increased functional connectivity resulting from either a larger number of small patches with smaller distances between them and/or a higher edge density

facilitating the movement of species that preferentially move along edges, increased landscape complementation with increased fragmentation, and positive edge effects (Fahrig 2003, 2017). Positive edge effects occur when edges are more productive and structurally diverse than interiors thus providing higher food availability and lower predation risk. If a species is favoured by edges then it is favoured by fragmentation because a fragmented landscape contains more edge.

The response of individual species to habitat fragmentation can be difficult to predict because fragmentation is an aggregate process that involves both a decline in the area of habitat and alteration of its spatial configuration (Yeager et al. 2016, Pavey et al. 2021). When considering changes in spatial configuration, a range of attributes have been shown to be important including patch size (the area of a fragment of potential habitat), patch isolation, number of patches, matrix (the areas between the remaining fragments) quality and edge characteristics. The connectivity of landscapes provides a measure of the impact of fragmentation. Connectivity describes the degree to which habitats are connected, enabling the movement of species and flow of ecological processes across landscapes.

Fragmentation of habitat through the establishment of roads, tracks and fire trails has both costs and benefits. Forest fragmentation can threaten the persistence of some animal and plant species including those of conservation concern. However, it can also facilitate management actions that reduce the threats faced by native species. Foremost among these management actions are fire prevention and greater accessibility to control the spread of feral animals.

Multiple approaches have been developed to measure and describe habitat fragmentation. Most approaches are designed to operate at a landscape or patch scale. More recent approaches have sought to develop metrics that harness the potential of earth observation science to measure fragmentation at large scales. The Foreground Area Density (FAD) is designed to provide a pixel-level measure of fragmentation. It describes the density of a foreground class of interest and was developed to track changes in forest fragmentation in the United States (Riitters and Wickham, 2012).

Similar to fragmentation, there are many methods and metrics for describing connectivity and many are designed to operate at landscape or patch scales. More recent approaches aligned with opportunities to harness larger datasets include the Morphological Spatial Pattern Analysis (MSPA), a pixel-level classification technique, and the Minimum Planar Graph (MPG), a flexible patch-level method based in graph theory.

The current proposal seeks funding for a project that will provide scientific knowledge of the current levels of habitat fragmentation across existing land uses in the Pilliga Forest and investigate the influence of fragmentation on the occurrence of threatened animals and plants. In parallel to threatened plant surveys, soil samples will be collected and ecto- and arbuscular mycorrhizal fungi will be identified using a DNA-based approach. The overarching aim is to determine whether habitat suitability of key components of the region's biodiversity will be impacted by fragmentation resulting from the NGP. By using recently available approaches and information from geospatial analysis and earth observation science, the project aims to maximise its usefulness to address a key concern of the community with regard to the NGP.

Prior Research

This research project has focused on the larger scale impacts from fragmentation based on the concerns of the local community expressed through a couple of platforms. The first of these is an on-line survey carried out in October 2021. CSIRO conducted the on-line survey to gather stakeholders' views on knowledge gaps or potential research topics across a range of social and environmental issues arising from onshore gas exploration and development activities. The stakeholders are people who live, work, or are interested in, gas exploration and development regions. In terms of biodiversity, the on-line stakeholder survey identified the following issues:

- Species degradation resulting from environmental changes.
- Effects on flora and fauna from gas wells.
- Effects on local ecosystems from the introduction of CSG including identification of at risk species and mitigation of risks.
- Potential loss of natural vegetation.

The second source of information on the concern of the local community comes from spoken and written submissions to the public hearing into the carrying out of the NGP conducted by the Independent Planning Commission of NSW (State of NSW 2020). Here, members of the public raised concerns over:
"*…fragmentation impacts resulting in detrimental edge effects and increased invasion of native vegetation communities by introduced predators and other pest animals and weeds*".

Previous research on the biodiversity of the Pilliga Forest has focussed on the impact of silvicultural management, specifically the thinning of forest regrowth, on plants and animals through restoring ecological complexity. A series of studies have been undertaken by the Forest Science unit of NSW Department of Primary Industries (previously State Forests of NSW), led by Dr Brad Law, examining the responses of bats, birds, invertebrates, reptiles, non-volant mammals, plants, and vegetation structure to thinning treatments (Law et al. 2016, Gonsalves et al. 2018, Waters et al. 2018). Changes in forest structure over time have been investigated by several researchers from NSW universities including Charles Sturt University, University of Wollongong, and Macquarie University (Norris et al. 1991, Whipp et al. 2012). The impact of fire on occurrence of insectivorous bats and Pilliga mouse (*Pseudomys pilligaensis*), and on overall stand structure has also received attention from academic research (Paull 2009, Whipp et al. 2013) and the Forest Science unit of NSW DPI (Law et al. 2018).

At the species level, the most well studied species in the Pilliga Forest is the Pilliga mouse. Multiple research projects through the University of New England and NSW government have focussed on the distribution, habitat, and population ecology of this species (Paull 2009, Paull et al. 2014, Tokushima and Jarman 2008, 2010, 2015, Tokushima et al. 2008).

In addition to the body of research summarized above, survey and distribution work on species of plants and vertebrate animals and on ecological communities within the NGP has been obtained

during the Environmental Impact Assessment phase of the project and during a series of surveys for various development proposals undertaken since 2002.

To date, no research has been undertaken to describe the pattern and extent of forest fragmentation in the Pilliga Forest or to assess the potential impacts of fragmentation on biodiversity in the region. Although the existing research (described above) is relevant to questions related to fragmentation, it does not directly address this important issue.

The vast majority of plant species, including threatened species, rely on specific associations with fungi called mycorrhiza. The availability of suitable mycorrhizal hosts has been shown to be important in the distribution of certain species (see for example, Reiter et al., 2020). Within the NGP area only one study was conducted and it only sampled a single site at Jacks Creek. The study revealed that numerous novel, cryptic, hypogeous ecotmycorrhizal species (including various *Tomentella* species) occurred in the area (Midgley et al., 2007). In addition to being critical for plant function, hypogeous fungi in particular also represent a key food source for small mammals, including the Pilliga mouse (Tokushima and Jarman, 2010) The diversity, abundance and distribution of mycorrhizal fungi represents a significant knowledge gap in the biodiversity of the NGP area. As with other organisms, fungi are potentially threatened by forest fragmentation.

The current project will draw on the findings of previous research and survey efforts, but it will have a central focus on understanding the current and future levels of forest fragmentation and the potential impact of fragmentation from development of the NGP on threatened species.

Need & Scope

The Pilliga Forest currently experiences multiple uses including nature conservation, recreation, forestry and soon, an onshore gas industry. The region is important to the Australian community which is strongly invested in its sustainable development; the public consultation phase of the EIA for the NGP generated 23,000 submissions to the NSW government (the highest number for any development in NSW history). Not all submissions raised concerns for biodiversity, but the report of the Independent Planning Commission of NSW from the further public hearing into the carrying out of the NGP (State of NSW 2020) specifically listed public concerns over forest fragmentation and the negative impacts of edge effects on biodiversity. The public raised concerns over 'localised population extinctions' from these processes (State of NSW 2020).

Fragmentation is foremost among the major impacts requiring mitigation and management during the NGP (Appendix J1 of Environmental Impact Assessment, pages 127-129). The development of the onshore gas industry in the Pilliga Forest will require the construction of a comprehensive inter-connected network of access roads and linear infrastructure linking well pads to transport infrastructure in addition to the construction of the Bibblewindi to Leewood corridor. The project will involve the clearing of 1,000 ha within the 95,000 ha project area. Up to 850 gas wells, on 425 well pads, will be constructed. These activities will increase the amount of forest fragmentation, creating

more patches and increasing the degree of isolation of some patches. The number of patches in the study area covered by the EIA is predicted to increase from 387 to 721. An increase in linear transport infrastructure and habitat clearing potentially threatens the biodiversity of the region. However, development is taking place in a landscape that is already fragmented from other land uses particularly activities associated with timber harvesting for forestry.

No research has been undertaken to describe the existing pattern and extent of forest fragmentation in the Pilliga Forest or to determine, at a fine-scale, the structural characteristics of the habitat of key threatened species in the region. This baseline information is needed in order to predict whether the environmental changes resulting from the NGP will impact the region's biodiversity. Therefore, this project will fill a major gap in knowledge of fragmentation of the region and in its effective management through an understanding of species-specific habitat requirements.

Almost no data exists on the mycorrhizal diversity within the NGP. Indeed, just a single sample was examined by Midgley et al., 2007 revealing a range of novel ectomycorrhizas. Some plant species have been shown to form highly specific mycorrhiza associations, while others form non-specific mycorrhizal associations. In the case of the former, this can severely hamper conservation efforts. Importantly, for the endangered plants of the region no information is available regarding their potential symbionts. Given the potential importance of mycorrhiza for the success of threatened plant species, it is important to establish which mycorrhizal fungi underpin threatened plant communities. Furthermore, those mycorrhizal fungi that have been observed in the NGP are known to produce subsurface (hypogeous) fruiting bodies that are a key food source for threatened ground-dwelling mammals and understanding the abundance and distribution of these hypogeous-fruiting species represents a significant knowledge gap that this study will address.

Objective

The overall objective of the project is to provide scientific understanding that addresses a key community concern related to maintaining the intactness of ecosystems and their component species in the Pilliga Forest. The project aims to do this through a combination of on-ground surveys using traditional methods and the latest approaches in geospatial analysis and earth observation science that allow the Pilliga region to be assessed at scale.

The specific objectives of the project are to:

1) Assess the level of fragmentation across landscapes with differing land uses (forestry versus conservation) in the Pilliga Forest, using fragmentation and connectivity metrics derived from remotely sensed imagery.

2) Determine whether fragmentation and connectivity indices are correlated with (a) the occupancy of sites by focal threatened species, and (b) the diversity and relative abundance of threatened plants and their associated mycorrhizal fungi in the region.

3) Quantify the structural habitat attributes currently occupied by each of the focal threatened species in the Pilliga Forest.

4) Assess whether the habitat suitability of each focal threatened species in the Pilliga Forest will be impacted by fragmentation resulting from the NGP.

5) Develop an ongoing framework for remote fragmentation monitoring in the Pilliga Forest during the life of the NGP.

Methodology

Activity 1: Assess fragmentation and connectivity using remote sensed imagery

Vegetation fragmentation and connectivity will be calculated using information obtained from high-resolution (10 m) woody vegetation cover (> 20 % woody cover fraction and > 2 m height) surfaces modelled using Sentinel 2A/2B composite images. Fragmentation describes the degree to which habitats form large contiguous blocks or smaller isolated patches. There are many approaches for describing habitat fragmentation (e.g., FRAGSTATS); however, to enhance the sensitivity of the pixel-level imagery produced from Sentinel composite images, we will use the Foreground Area Density (FAD) approach. The FAD describes the density of a foreground class of interest. The FAD is calculated as the proportion of foreground pixels (e.g., pixels associated with forest cover) that occur within a moving window across an image. The multi-scale FAD allows local fragmentation to be quantified in the context of regional patterns. For example, small fragments of forest will score more highly where in proximity to larger contiguous patches. Conversely, the interior cores of large contiguous forest patches will score more highly than the those of small to moderately sized forest patches.

Connectivity describes the degree to which habitats are connected, enabling the movement of species that require continuous cover. We will use two distinct approaches to assess connectivity: 1) Morphological Spatial Pattern Analysis (MSPA), a pixel-level classification technique, and 2) Minimum Planar Graph (MPG), a flexible patch-level method based in graph theory. The MSPA provides a general approach to characterizing structure in binary patterns. The MSPA uses mathematical morphometry techniques (e.g., erosion) to classify binary patterns into discrete classes. These classes include cores, edges, and bridges, that can be used to assist in identifying important habitat patches, patch characteristics, and components of the landscape that connect core habitats to one another. The MPG approach will be used to isolate and visualize core patches across the landscape.

Activity 2: Complete on-ground surveys of occupancy of focal threatened species and alpha diversity and abundance of mycorrhizal fungi

On-ground surveys will be undertaken for focal threatened species of animals and plants and their mycorrhizal symbionts. The animal species that will be targeted are the pale-headed snake, squirrel glider, eastern pygmy-possum, and black-striped wallaby. The plant species that will be targeted are: coolabah bertya (*Bertya opponens*), spiny peppercress (*Lepidium aschersonii*), winged peppercress

(*Lepidium monoplocoides*), *Commersonia procumbens* and *Tylophora linearis*. Occupancy surveys will use species-specific methods that have been already found to be successful from previous research. Surveys will be undertaken at the most suitable times of the year for each target species. Mycorrhizal fungi diversity will be conducted in parallel with plant surveys and will use a DNA-based approach (next generation sequencing of the internal transcribed spacer region). This approach will use two PCR primer sets to profile ectomycorrhizal and arbuscular mycorrhizal communities associated with threatened plant species. Bioinformatics will then be used to analyze mycorrhizal diversity and abundance.

Activity 3: Assess structural attributes of habitat currently occupied by each of the focal threatened species

Following completion of threatened species occupancy surveys , the structural attributes of sites occupied by focal threatened species will be quantified using light detection and ranging (LiDAR) to enable monitoring of habitat condition over the life of the NGP project. The 3D structure of habitat occupied by threatened species will be quantified with UAV LiDAR scanning. The size of survey plots (10 to 100 ha) will be scaled to the spatial ecology of the focal species and will aim to capture a representative sample of the species' habitat. A survey grade multi-angle UAV LiDAR sensor (Riegl VZ-2000i) will be used to scan the selected sites from 80-100 m above ground level. Point clouds derived from individual flight lines will be merged into a cohesive 3D model from which a suite of structural metrics will be calculated to assess structural biodiversity and availability of key habitat components (for example, tree hollows for squirrel gliders).

Activity 4: Predict potential impacts on habitat suitability of focal threatened species from fragmentation during the NGP

By matching information on the fragmentation and connectivity indices of the landscapes in which each of the focal threatened species is recorded (activities 1 and 2) with LiDAR-derived data on structural attributes of each species' habitat, predictions will be made on the likely population-level response of each species to additional forest fragmentation resulting from the NGP. Any focal threatened species, the persistence of which in the region is threatened by this additional fragmentation, will be identified through this qualitative matching of habitat requirements with landscape metrics. Although it may seem counterintuitive, threatened species may not necessarily be negatively impacted by additional forest fragmentation. Given the long history of forest fragmentation in the region, it is possible that most of the remaining species are able to persist in fragmented landscapes. A case study of such a situation is the golden-tailed gecko (*Strophurus taenicauda*) in the Brigalow Belt of central Queensland (Pavey et al. 2021).

If necessary, species distribution modelling will be undertaken to map changes in the availability of suitable habitat for each species in the region post-NGP.

Activity 5: Explore approaches to upscale monitoring to enable remote assessment of environmental variables during the life of the NGP

UAV LiDAR is an emerging tool for local scale characterisation of habitat structure and dynamics, providing insights that cannot be measured through traditional fieldwork. However, given the large extent of the Pilliga study area the use of satellite remote sensing should be investigated for larger scale and ongoing monitoring. The use of Synthetic Aperture Radar (SAR) for measuring and monitoring the structure of key habitats within the Pilliga Forest will be investigated for this purpose. The analysis will primarily make use of C-band Sentinel-1 data (10 m spatial resolution, 10-day revisit time) which is sensitive to vegetation structural elements but may include the upcoming L-band data from NASA's NISAR mission if it is successful (scheduled for mid-2023). The SAR based analyses will be trained and validated with the terrestrial LiDAR data obtained during the previous activity. Remote monitoring provides the opportunity for long-term monitoring of habitat condition over time, potentially over the life of the NGP.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Chris Pavey	135 days	Terrestrial ecology: threatened species, impact assessment, monitoring, fauna survey	30 years	CSIRO
Shaun Levick	50 days	Geospatial analytics; Spatial ecology including habitat condition monitoring, LiDAR, SAR, multi-spectral imagery	15 years	CSIRO
Steph Johnson	110 days	Geospatial analytics; field ecology	5 years	CSIRO
David Midgley	10 days	Mycorrhizal biology, bioinformatics	20 years	CSIRO
Nai Tran-Dinh	20 days	Mycology	20 years	CSIRO
Carla Mariani	15 days	Molecular biology	5 years	CSIRO
Eric Vanderduys	40 days	Terrestrial ecology: fauna survey, GIS, species distribution modelling	30 years	CSIRO
Stewart MacDonald	15 days	Species distribution modelling, field survey	10 years	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Survey botanists	50 days	Plant survey, taxonomy		NSW Herbarium

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 which may include:

- Government researchers: Forest Science unit of NSW Department of Primary Industries.
- Technical expertise: remote sensing (CSIRO Land and Water).
- Technical expertise: fragmentation and road ecology (WSP).
- Company representatives: SANTOS.

Budget Summary

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
GISERA	$160,810	$448,142	$0	$0	76%	$608,952
- Federal Government	$135,768	$378,355	$0	$0	64.16%	$514,123
- NSW Government	$20,243	$56,412	$0	$0	9.57%	$76,655
- Santos	$4,799	$13,374	$0	$0	2.27%	$18,174
Total Cash Contributions	**$160,810**	**$448,142**	**$0**	**$0**	**76%**	**$608,952**

Source of In-Kind Contribution	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
CSIRO	$50,782	$141,518	$0	$0	24%	$192,300
Total In-Kind Contribution	**$50,782**	**$141,518**	**$0**	**$0**	**24%**	**$192,300**

TOTAL PROJECT BUDGET	2022/23	2023/24	2024/25	2025/26	-	TOTAL
All contributions	**$211,592**	**$589,660**	**$0**	**$0**	**-**	**$801,252**
TOTAL PROJECT BUDGET	**$211,592**	**$589,660**	**$0**	**$0**	**-**	**$801,252**

4. Communications Plan

Stakeholder	**Objective**	**Channel** (e.g. meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Regional community stakeholders/wider public including land holders and traditional owners.	To communicate project objectives and key messages from the research	A fact sheet at commencement of the project which explains in plain English the objective of the project. Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities.	At commencement of project Ongoing
Gas Industry	Industry understands implications of primary research findings	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At project completion
Government	Data is available in the appropriate databases that meet the requirements of the NSW Monitoring, Evaluation and Reporting Program (MER) framework	Meet with appropriate senior staff from NSW Department of Planning and Environment's Environment and Heritage Group (EHG) and NSW Department of Primary Industries' (DPI) Forestry group about suitability of SEED (Sharing and Enabling Environmental Data) and BioNet databases as repositories for data from this project.	Within 6 months of project commencement.
Government	Advice provided to senior bureaucrats / ministers / policy makers	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At project completion
Regional community/wider public, government, scientific community and industry	To report on key findings of the research project.	Public release of final report. Plain English factsheet summarising the outcomes of the research. Preparation of article for GISERA newsletter and other media outlets as advised by GISERA's communication team Presentation of research findings to regional community stakeholders such as business and/or community groups (e.g., Narrabri CCC) will be invited to a community forum (virtual or face-to-face) to learn of research results.	At project completion. At project completion At completion or within 6 months of completion of the project.

Stakeholder	**Objective**	**Channel** (e.g. meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Scientific Community	To present research findings to the scientific community in Australia and globally focussed on forest fragmentation research.	At least one peer-reviewed scientific publication in an international journal. At least one presentation at a national and an international conference.	During or within 6 months of completion of the 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 communications products.

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Assess fragmentation and connectivity using remote sensed imagery.	Metrics and mapping of fragmentation and connectivity of forest across selected landscapes in the Pilliga Forest.	Scientific understanding of baseline levels of forest fragmentation across land use types in the Pilliga Forest.	Government regulators have improved scientific knowledge to consider when making future management decisions related to forest fragmentation in the Pilliga Forest. Onshore gas industry has improved knowledge of the effects of habitat clearance and fragmentation on biodiversity during construction and operation of gas infrastructure.	Improved community understanding of the potential impacts of onshore gas industry on biodiversity. Improved biodiversity management by the onshore gas industry. Application of leading edge technology from earth observation science into environmental monitoring increasing cost effectiveness, replicability, and transparency.
Complete on-ground surveys of occupancy of focal threatened species and diversity and relative abundance of mycorrhizal fungi.	Site-specific presence/absence records of focal threatened plants and animals and diversity and relative abundance of mycorrhizal fungi.	Scientific understanding of correlation of fragmentation indices with (a) the occupancy of sites by focal threatened species, and (b) diversity and relative abundance of mycorrhizal fungi.		
Assess structural attributes of habitat currently occupied by each of the focal threatened species.	Cohesive 3D models of habitat of each species and quantification of structural metrics identifying key habitat components.	Scientific understanding of habitat requirements of each focal threatened species.		
Predict potential impacts on habitat suitability of focal threatened species from fragmentation during the NGP.	Qualitative assessment of the likely response of each focal species to additional fragmentation from the NGP.	Identification of focal threatened species whose persistence is potentially threatened by forest fragmentation caused by development of an onshore gas industry.		
Explore approaches to upscale monitoring to enable remote assessment of environmental variables during the life of the NGP.	Pilot study of usefulness and reliability of potential spaceborne approaches to remotely assess environmental variables in the Pilliga Forest.	A field-tested approach to remote monitoring of change in environmental variables over the life of the NGP.	A cost-effective approach to long-term monitoring of the impacts of onshore gas development on the natural environment.	
Stakeholder engagement.	Information on the GISERA website. Presentations at research and community workshops/open days/road shows. Factsheets. Media appearances.	Community informed about scientific findings relevant to concerns about environmental impacts of onshore gas development especially fragmentation and species persistence.	Greater trust between the community, industry, government, and CSIRO.	

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Assess fragmentation and connectivity using remote sensed imagery.	Steph Johnson	10 January 2023	30 June 2023	None.
Task 2	Complete on-ground surveys of occupancy of focal threatened species diversity and relative abundance of mycorrhizal fungi.	Chris Pavey	10 January 2023	31 December 2023	Task 1.
Task 3	Assess structural attributes of habitat currently occupied by each focal threatened species.	Shaun Levick	1 September 2023	31 March 2024	Task 2.
Task 4	Predict potential impacts on habitat suitability of focal threatened species from fragmentation during the NGP.	Chris Pavey	1 December 2023	31 May 2024	Tasks 1, 2 and 3.
Task 5	Explore approaches to upscale monitoring to enable remote assessment of environmental variables during the life of the NGP.	Shaun Levick	1 March 2024	30 June 2024	Task 3.
Task 6	Project reporting	Chris Pavey	30 June 2023	30 June 2024	Tasks 1 to 5.
Task 7	Communicate findings to stakeholders	Chris Pavey	10 January 2023	30 June 2024	None.

Task description

Task 1: Assess fragmentation and connectivity using remote sensed imagery.

OVERALL TIMEFRAME: 10 January to 30 June 2023.

BACKGROUND: The development of the NGP requires clearing of vegetation and will increase forest fragmentation. The number of patches in the study area covered by the Environmental Impact Assessment is predicted to increase from 387 to 721. The public has raised concerns over forest fragmentation and potential negative impacts of edge effects on biodiversity including localised population extinctions of species. However, the Pilliga region is already fragmented through a major road network (including the Newell Highway) and the provision of roads and tracks for forestry activities. To date, no research has been undertaken to describe the existing pattern and extent of forest fragmentation in the Pilliga Forest. This task addresses that issue.

TASK OBJECTIVES: To quantify the current levels of forest fragmentation in landscapes of the Pilliga Forest with differing land uses (forestry versus conservation).

TASK OUTPUTS AND SPECIFIC DELIVERABLES: The main output will a database that for each of approximately 10 landscapes calculates fragmentation and connectivity metrics using the methods of Foreground Area Density, Morphological Spatial Pattern Analysis and Minimum Planar Graph.

The results will be discussed in the final report for the project. There are no specific deliverables for this task; however mapping outputs will be used in subsequent tasks.

Task 2: Complete on-ground surveys of occupancy of focal threatened species and diversity and relative abundance of mycorrhizal fungi.

OVERALL TIMEFRAME: 10 January to 31 December 2023

BACKGROUND: The public has raised concerns over the impacts of fragmentation from the NGP on persistence of 'at risk' species and on ecosystem functioning. The current task is examining whether the fragmentation and connectivity metrics (from task 1) are correlated with patterns of occupancy of focal threatened species and diversity of mycorrhizal fungi. Four species of threatened animals and five species of threatened plants have been chosen as the focal species for the occupancy surveys. These species are: pale-headed snake, squirrel glider, eastern pygmy-possum, black-striped wallaby, coolabah bertya (*Bertya opponens*), spiny peppercress (*Lepidium aschersonii*), winged peppercress (*Lepidium monoplocoides*), *Commersonia procumbens* and *Tylophora linearis*.

TASK OBJECTIVES:

The task has three key objectives.

1) To carry-out on-ground surveys for each of four focal species of threatened vertebrate using appropriate sampling approaches at the appropriate time of year to enhance detection.

2) To carry-out on-ground surveys for each of five focal species of threatened plants at the time of year that maximises the presence of individuals above-ground.
3) To collect samples of plants and soil for subsequent laboratory analyses of diversity of mycorrhizal fungi.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:
The main output will be a spreadsheet of site-specific presence/absence records of the focal threatened plants and animals and alpha diversity measures for fungi.

The results will be discussed in the final report for the project; there are no specific deliverables for this task.

Task 3: Assess structural attributes of habitat currently occupied by each of the focal threatened species.

OVERALL TIMEFRAME: 1 September 2023 to 31 March 2024

BACKGROUND: Understanding what environmental factors make an area suitable for a species is essential information in order to effectively manage for the species' persistence. LiDAR is a technology that provides an unprecedented opportunity to cost-effectively quantify the structural attributes of an area. Methods have been developed that enable a 3D map of an area to be developed that can then be used to derive variables such as height, volume, foliage cover, and presence of tree hollows. This approach can be applied to understanding the environmental characteristics of the habitat of a species.

TASK OBJECTIVES: The objective of this task is to quantify the 3D structure of habitat occupied by each of the focal species. This will be achieved by using a survey grade UAV LiDAR system to map vegetation structure in high-resolution detail.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: The main output will be a database of LiDAR derived structural metrics that represent the habitat structure of each of the focal species.

Deliverables will include geolocated LiDAR point clouds for each study sites, and a short report detailing the analytical workflow and key findings.

Task 4: Predict potential impacts on habitat suitability of focal threatened species from fragmentation during the NGP.

OVERALL TIMEFRAME: 1 December 2023 to 31 May 2024.

BACKGROUND: Tasks 1 and 2 will provide understanding on the degree of fragmentation of the landscapes in which each focal threatened species persists in the Pilliga Forest. Together with the LiDAR-derived data on structural attributes of habitat, this will enable predictions to be made on the likely population-level response of each species to additional forest fragmentation resulting from the NGP. Any focal threatened species, the persistence of which in the region is threatened by this additional fragmentation, will be identified through this qualitative matching of habitat requirements with landscape metrics.

TASK OBJECTIVES: To predict the likely response of each focal threatened species to additional forest fragmentation resulting from the NGP.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: The main output will be the identification of those focal threatened species whose persistence is potentially threatened by forest fragmentation caused by development of an onshore gas industry.

This information will be discussed in a short report. The results will be discussed in detail in the final report for the project

Task 5: Explore approaches to upscale monitoring to enable remote assessment of environmental variables during the life of the NGP.

OVERALL TIMEFRAME: 1 March to 30 June 2024

BACKGROUND: LiDAR is a powerful tool for 3D habitat characterisation at plot to landscape scales. Repeat LiDAR provides unique insights into ecosystem dynamics, but the cost and complexity of acquisition hinder its scalability for long-term monitoring. Wall-to-wall mapping from spaceborne satellites is a more cost-effective avenue for habitat monitoring, but the sensitivity of different spaceborne sensors to habitat structural attributes needs verification. This Task will use LiDAR point clouds collected in Task 3 to calibrate and validate structural metrics derived from satellite SAR sensors.

TASK OBJECTIVES: The main objective of this task is to determine how well spaceborne SAR can capture the structural elements of the Pilliga scrub habitat that are important for the focal species.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: GIS layers of SAR derived structural features (GEOTIFF format) will form the primary outputs, together with a short report detailing the workflow and key findings.

Task 6: Project Reporting

OVERALL TIMEFRAME: 30 June 2023 to 30 June 2024

BACKGROUND: All aspects of reporting are covered in this task.

TASK OBJECTIVES: To report on the results of the research to relevant stakeholders including the public, GISERA and the Australian government.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: There are three task outputs and deliverables.

1) Preparation of a final report outlining the scope, methodology, scenarios, assumptions, findings, and any suggestions/options for future research.

2) Following CSIRO ePublish review, the report will be submitted to the GISERA Director for final approval.

3) Provide 6 monthly progress updates to GISERA office.

Task 7: Communicate project objectives, progress and findings to stakeholders

OVERALL TIMEFRAME: Full duration of project

BACKGROUND: Communications of GISERA research are an important component of outreach and dissemination of findings to diverse audiences.

TASK OBJECTIVES: Communicate project objectives, progress and findings to stakeholders through meetings, knowledge transfer session, factsheet and journal article, in collaboration with GISERA Communications officers.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communicate project objectives, progress, and results to GISERA stakeholders according to standard GISERA project procedures which may include, but not limited to:

1) Knowledge Transfer session with Government/Gas Industry
2) Presentation of research findings to regional community stakeholders such as business and/or community groups (e.g. Narrabri CCC) will be invited to a community forum (virtual or face-to-face) to learn of research results.
3) Preparation of article for GISERA newsletter and other media outlets as advised by GISERA's communication team
4) Two project factsheets: A factsheet, hosted on the GISERA website, will be developed at commencement of project, and another that will include peer-reviewed results and implications will be developed at completion of project.
5) Peer reviewed scientific manuscript ready for submission to relevant journal.

Project Gantt Chart

		2022/23						2023/24											
Task	**Task description**	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24
1	Assess fragmentation and connectivity																		
2	On-ground surveys																		
3	Structural attributes of habitat																		
4	Predict potential impacts																		
5	Upscale monitoring																		
6	Project Reporting																		
7	Communication activities																		

7. Budget Summary

Expenditure	2022/23	2023/24	2024/25	2025/26	Total
Labour	$153,842	$463,660	$0	$0	$617,502
Operating	$25,250	$93,500	$0	$0	$118,750
Subcontractors	$32,500	$32,500	$0	$0	$65,000
Total Expenditure	**$211,592**	**$589,660**	**$0**	**$0**	**$801,252**

Expenditure per task	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$72,649	$0	$0	$0	$72,649
Task 2	$123,718	$290,457	$0	$0	$414,175
Task 3	$0	$141,252	$0	$0	$141,252
Task 4	$0	$15,859	$0	$0	$15,859
Task 5	$0	$27,019	$0	$0	$27,019
Task 6	$0	$69,470	$0	$0	$69,470
Task 7	$15,225	$45,603	$0	$0	$60,828
Total Expenditure	**$211,592**	**$589,660**	**$0**	**$0**	**$801,252**

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (64.16%)	$135,768	$378,355	$0	$0	$514,123
NSW Govt (9.57%)	$20,243	$56,412	$0	$0	$76,655
Santos (2.27%)	$4,799	$13,374	$0	$0	$18,174
Total Cash Contributions	**$160,810**	**$448,142**	**$0**	**$0**	**$608,952**

In-Kind Contributions	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (24%)	$50,782	$141,518	$0	$0	$192,300
Total In-Kind Contributions	**$50,782**	**$141,518**	**$0**	**$0**	**$192,300**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$514,123	64.16%
NSW Government investment	$76,655	9.57%
Santos investment	$18,174	2.27%
CSIRO investment	$192,300	24.00%
Total Expenditure	**$801,252**	**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	Assess fragmentation and connectivity using remote sensed imagery.	GISERA	Jan-23	Jun-23	2022/23	$55,213
Task 2	2.1	Complete on-ground surveys of occupancy of focal threatened species and diversity of mycorrhizal fungi.	GISERA	Jan-23	Dec-23	2023/24	$314,773
Task 3	3.1	Assess structural attributes of habitat currently occupied by each focal threatened species.	GISERA	Sep-23	Mar-24	2023/24	$107,352
Task 4	4.1	Predict potential impacts on habitat suitability of focal threatened species from fragmentation during the NGP.	GISERA	Dec-23	May-24	2023/24	$12,053
Task 5	5.1	Explore approaches to upscale monitoring to enable remote assessment of environmental variables during the life of the NGP.	GISERA	Mar-24	Jun-24	2023/24	$20,534
Task 6	6.1	Project reporting	GISERA	Jun-23	Jun-24	2023/24	$52,797
Task 7	7.1	Communicate findings to stakeholders	GISERA	Jan-23	Jun-24	2023/24	$46,229

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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