This template should be completed in response to the Proposal Guidelines.

Organisation / Partner Name:	Salo Sciences
Partnership duration:	13 weeks (maximum 6 months)

Organisational Details

Name: Salo Sciences, Inc.
Employer Identification Number (EIN): 812798820
Address: 235 Kansas St. #205
Website: https://salo.ai
Organisation description: Salo Sciences is a conservation technology company that builds mapping and marketplace systems to monitor and mitigate the impacts of climate change.
Key Personnel:

- David Marvin, Ph.D., Science lead
- Christopher Anderson, Ph.D., Technical lead
- Kyle Gertridge, J.D., Partnership lead

Contact Details

Salo Lead Contact: David Marvin
Role: Co-founder & CEO
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Values

Salo Sciences develops solutions to climate change and biodiversity loss. We work to guide investments in natural climate solutions—conservation, restoration & improved land stewardship—by leveraging satellite data, ecological modeling & artificial intelligence. We think of ourselves as equal parts ecologists, environmentalists & technologists.

As a bootstrapped company with a global vision—founded and self-funded by ecologists, and 100% employee-owned—we are always pushing ourselves to meet ambitious **stretch targets** that require us to think big and think creatively (**generating ideas**). The California Forest Observatory, our next generation forest monitoring system, was designed, developed, and launched within a year on the promise to be ready in time for the 2020 wildfire season. This was a critical deadline to establish our **integrity** by executing on big ideas that have operational impact. We made the data products—high resolution maps of the fuels that drive wildfire behavior—available for free to public agencies, helping **empower** government decision makers to make informed choices about wildfire risks. It is critical to share these data with the right partners, knowing that we make better decisions when we all work together (**humility**).

Organisation Due Diligence

Representation and Warranty Certificate completed and submitted by Salo on 10/5/2021

Context

Bushfire frequency, intensity, and impact are driven by complex interactions between weather, fuels, topography, and community infrastructure. During the 2019-2020 fire season, the weather and fuel conditions created a fire feedback loop—2019 was the hottest and driest year on record, following a multi-year drought that stressed plant communities in the southeast—leading to catastrophic losses of life, property, and natural capital.

Active planning, forecasting, and intervention will be key tools to mitigate the likelihood and the impacts of future catastrophic bushfire seasons. Each of these steps will rely, to some degree, on data-driven decision making, and the coordination of activities across teams will be more direct and more transparent if stakeholders are all working with the same set of information.

Given how recent, extensive, and localized the impacts of the 19/20 bushfire season were, this shared information should be:

1) up-to-date, reflecting current conditions as the coming fire season approaches
2) comprehensive, mapping contiguous areas across large extents to see the full picture
3) high resolution, capturing the detail and nuance of each landscape

To meet these criteria, and to support bushfire planning, forecasting and intervention, this proposal outlines a plan to develop contemporary, satellite-based maps of tree-scale vegetation fuels across New South Wales over several project iterations.

Vegetation is dynamic: it responds to changes in weather and climate conditions, regrows and disperses following a fire, and provides habitat to tree-dwelling species and tree-loving people alike. It is also a key “lever” in mitigation: vegetation can be cleared, thinned, or proactively burned to reduce hazardous exposure.

Current approaches to operational vegetation mapping are labor-intensive and often subjective processes, relying on expert technicians to manually update maps. This isn’t well-suited to address the rapidly-changing needs for planning, forecasting and intervention. A popular alternative is airborne LiDAR, an expensive ($400 per 1200 km^2) and time-consuming process that does not scale well. We need a new approach.

Currently vegetation fuel mapping used by NSW RFS is at 200m resolution, this project looks to improve this by providing 10m resolution vegetation mapping.

This project proposes to expand, modify, and deploy the forest monitoring technology built by Salo Sciences to New South Wales to develop novel maps of the vegetation formations that drive fire behaviour. These data will be made available to key bushfire personnel for evaluation and feedback.

The first scope of the project (Phase 1) will be to develop a prototype mapping system in a few limited areas of interest to show proof-of-concept, develop trust and accountability between partners, and flesh out the design requirements for a larger fuels mapping and monitoring system. A follow-on scope of the project (Phase 2) will be the development of an operational vegetation mapping and monitoring system that provides regular updates for the entirety of NSW and other key fire-prone regions of Australia.

The Minderoo Foundation, a key enabler of systemic change, has laid out a series of ambitious missions under their Fire & Flood Resilience Initiative. These aim to reduce the scale and impact of bushfires, and to simultaneously increase resilience and reduce hazardous exposure by half in vulnerable communities. Minderoo convenes stakeholders, decisionmakers, and innovators to foster collaboration and accelerate impact, and they reached out to Salo Sciences as an innovator who can rapidly accelerate the impact of other projects funded through the Fire Shield and Healthy Landscapes Missions.

Project

The scope of work for this proposal will cover Phase 1, with a Phase 2 follow-on to be considered at a later date. We propose to develop novel maps of vegetation fuels, including floristic composition and patterns of ecosystem structure, using high resolution satellite imagery that are compatible with the Phoenix RapidFire (used by RFS) and Spark Operational (planned as forthcoming national system) bushfire simulation systems.

Inputs and Activities:

Creating custom, up-to-date fuel maps based on the following Inputs:

- Requirements gathering and research, including expert guidance on defining fuel class definitions from NSW RFS
- 10m resolution satellite imagery and ancillary remotely sensed data layers, Sentinel satellite constellation (sourced by Salo) and other government agency produced data
- 3D airborne LiDAR data from NSW Department of Customer Service
- 1.5m resolution SPOT satellite imagery from Airbus, or higher where available, from NSW Department of Customer Service (optional and not required to produce deliverables for phase one)

Activities needed to generate Outputs, all performed by Salo:

- Salo Sciences cloud-based, forest-focused deep learning system experimentation, training, and application
- Model and data layer accuracy evaluation and assessment
- QA/QC of output data layers
- Data introduction and orientation to end-users
- Develop data documentation and accuracy report
- Follow-up guidance on data interpretation, application, and modification

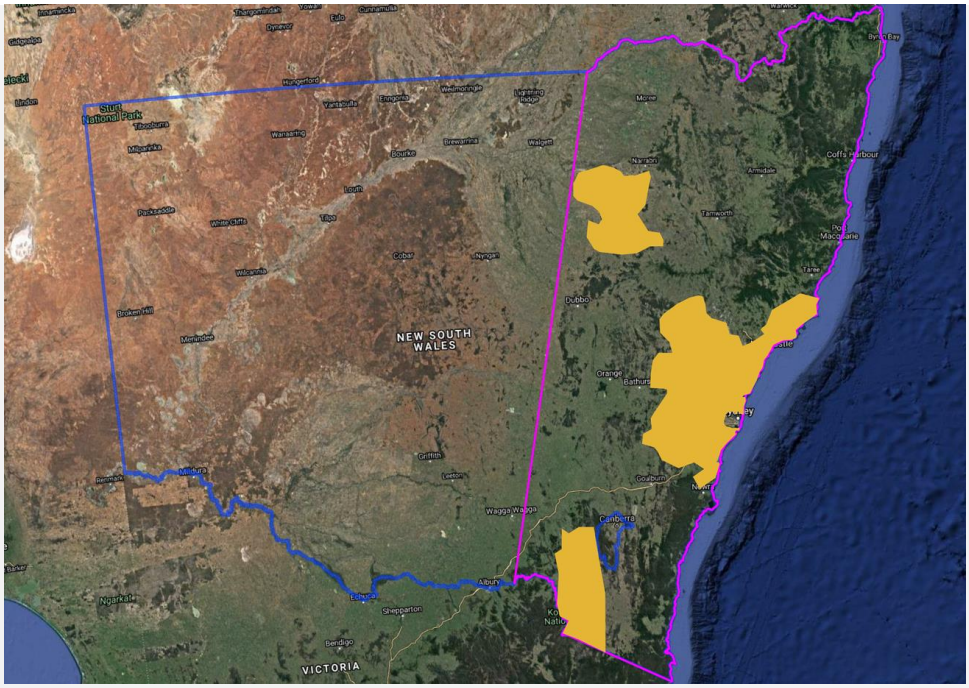
Project Milestones and Timeline:

Assuming a grant agreement is executed by Dec 24, 2021, we anticipate delivery of Beta pilot layers to RFS for review by Feb 4, 2022, with version 1 pilot layers delivered by Apr 8, 2022. Pilot completion would be TBD and dependent on RFS engagement but we anticipate earliest completion to be in mid-April 2022. This first phase of the project should not go beyond more than 6 months. Milestones not denoted as *Key Milestones below are tentative and may be adjusted based on project progress, needs, and collaborative input from the partners.

Everything following Milestone 1 is dependent on the date Salo receiving all LiDAR data to then begin the downstream work, due dates to depend on that date of receipt. LiDAR Receipt is defined as the Friday after Salo receive the data so that each Milestone due date is on a subsequent EOW Friday.

Locations:

- Phase 1 outputs will be limited in extent to a series of areas totalling no more than 70,000km$^{2.}$ The locations have been determined by NSW RFS, outlined in the below coarse area of interest map.



Project overview: Pilot areas (orange polygons) in eastern NSW (purple outline).

Exit Strategy:

- The IP strategy of the California Forest Observatory was to make the initial data release (2016-2020) freely available to government agencies, research institutions, and non-profits, while licensing the data for a fee to commercial organizations. The strategy has been, in part, to demonstrate the value of the Forest Observatory to the public institutions that benefit from its data in order to secure mid- to long-term contracts to provide regularly-updated data on an ongoing basis. It is important to establish buy-in from government agencies early because they are typically conservative institutions, hesitant to invest in innovation. But they are eager to support mapping systems that provide demonstrable public benefit, and have shown willingness to pay following deep engagement, from design to delivery to deployment.

Evidence of Effectiveness:

- Salo Sciences launched the California Forest Observatory in September 2020, which has been used by numerous state and federal agencies, local fire departments, major utilities, and conservation organizations to map vegetation fuels and hazardous exposure. In the fire prone Bay Area, CALFIRE has used our fuels data in a wildfire mitigation plan for San Mateo County and the Moraga-Orinda Fire District uses our fuels data for a multi-year fuel reduction effort. See Appendix A for highlighted use cases and organizations using data from the Forest Observatory.
- Salo Sciences is working now to expand the extent of the Forest Observatory to ten more states in the western US, and this expansion is possible because of the scalability of our mapping approach and our technology system.
- Though the fuel classes differ between American and Australian fire simulation models, the vegetation mapping approach is flexible enough to accommodate these differences with input from subject matter experts.

Milestones (***Key Milestone**)	Deliverable/ Activity	Expected Timing	Due Date	Responsible parties

***Milestone 1: Grant Execution**	● Discussions with RFS to define fuel class definitions (may occur before project start date) and the threshold for fuels layer improvement ● Collect existing maps and data used to define fuels in NSW ● Research into floristic and structural properties of each class ● Receipt Salo of all necessary LiDAR data from Spatial Services (or elsewhere) (the Friday following such date, the "LiDAR Receipt Date") ● NSW RFS providing	Week 1	3rd January, 2022	Salo, NSW RFS
Milestone 2	● Begin processing lidar ● Begin processing Sentinel 1 and 2 satellite imagery for the AOIs and TOIs ● Create framework for novel vegetation fuels model (i.e., converting vegetation structure and ancillary layers to fuels classes)	Week 2	LiDAR Receipt + 1 week	Salo
Milestone 3	● Conclude lidar and satellite imagery processing ● Multi-sensor fusion of input satellite imagery (feature dataset), including resampling, co-registration, and transformation ● Tilling of co-aligned feature data and airborne lidar	Week 3	LiDAR Receipt + 2 weeks	Salo
Milestone 4	● Deep learning model experimentation and training for vegetation structure layers ● Application of top models to AOIs	Week 4	LiDAR Receipt + 3 weeks	Salo
***Milestone 5: Receipt of LiDAR data from NSW RFS and delivery of Beta pilot layers and progress report for Minderoo**	● LiDAR data provided to Salo ● Beta version of vegetation structure and fuels shared with RFS ● Progress report provided by the Salo team to Minderoo	Week 5	LiDAR Receipt + 4 weeks	Salo & NSW RFS

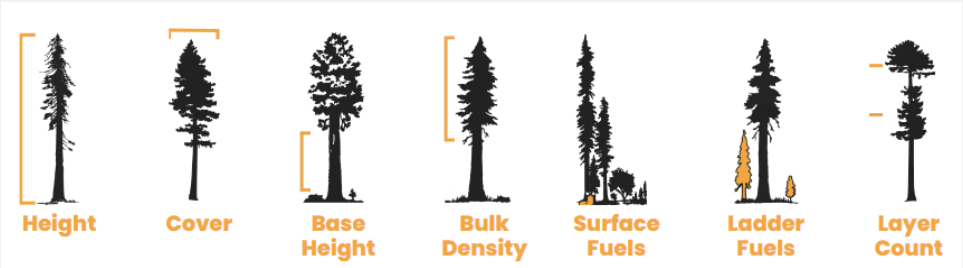
Milestone 6	● Refinement of vegetation structure models ● Refinement of novel vegetation fuels model ● Model and data validation, and comparison to existing fuels maps ● Produce v1 structure and fuels layers	Week 6- 8	LiDAR Receipt + 7 weeks	Salo
Milestone 7	● QA/QC of v1 layers ● Develop data orientation and initial documentation	Week 9	LiDAR Receipt + 8 weeks	Salo
***Milestone 8: Delivery of v1 pilot layers**	● Deliver v1 layers to RFS for internal evaluation ● Data introduction and orientation to RFS	Week 10	LiDAR Receipt + 9 weeks	Salo, NSW RFS
Milestone 9: Evaluation	● In-depth model and layer accuracy assessment ● In-depth comparison to existing fuels maps ● Evaluation report provided by NSW RFS	Week 11	LiDAR Receipt + 10 weeks	Salo, NSW RFS
Milestone 10	● Create report documenting data layers, methods, accuracy, and comparison to existing fuels	Week 12	LiDAR Receipt + 11 weeks	
***Milestone 11: Completion of pilot, reporting of accuracy produced and project scope for all of NSW**	● Accuracy produced ● Final Narrative Report & Financial Acquittal ● Preliminary report on scaling to all of NSW, additional jurisdictions This depends on RFS's ability to engage and provide feedback on the v1 layers (milestone 3). During this period Salo will iteratively revise and produce new versions of the structure and fuels layers based on RFS input and provide guidance to RFS on use of the new layers. Salo will also engage RFS and other potential end users in NSW on the scope and high-level requirements for an operational fuels mapping and monitoring system covering a larger extent of NSW. If at any time the deliverables meet or exceed the threshold of improvement defined in Week 1, the pilot will be deemed complete.	Week 13+	LiDAR Receipt + 12 weeks onwards, but no later than thirty (30) days following delivery of all deliverables, provided Salo has produced at least one revision to the v1 layers in the event NSW RFS has requested	Salo, NSW RFS

			such revisions.	

Outputs

Phase 1 will produce three key deliverables outlined below:

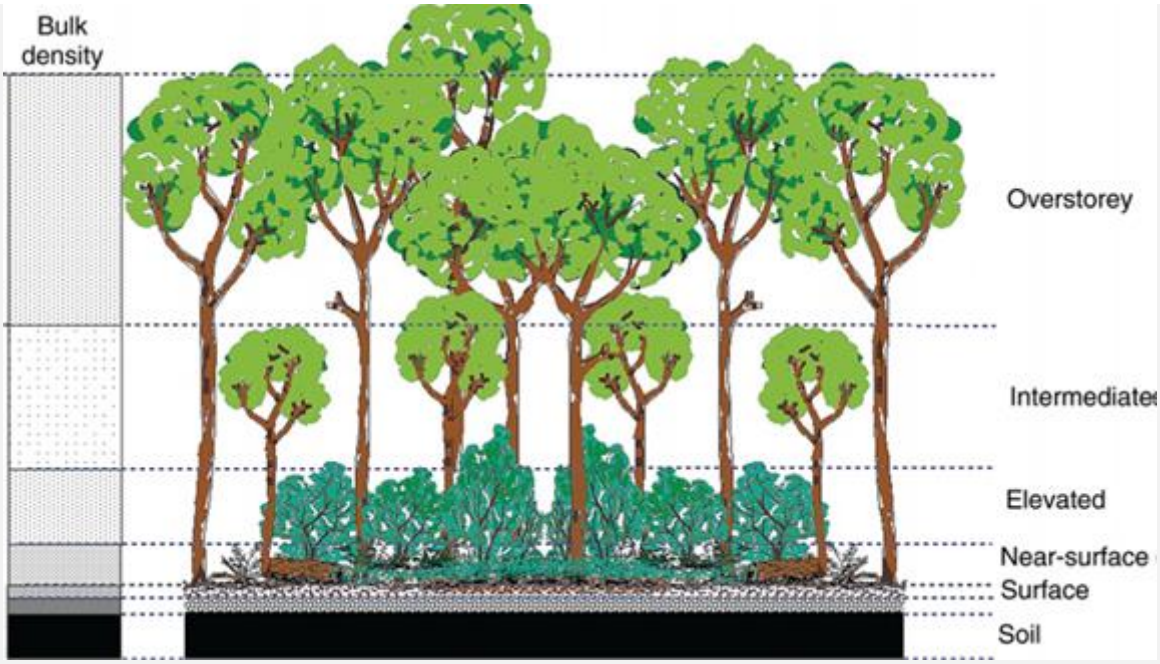
1. 10x10m resolution maps (rasters in cloud-optimized geotiff format) of vegetation fuels datasets covering the extent of the test regions totalling 70,000kms^2, expected to be (but ultimately to be defined jointly by NSW RFS, Salo and Minderoo) (the "Data Deliverables"):
   - Vegetation fuel formations (17 groups)
   - Vegetation fuel classes (52 groups)
   - Canopy cover
   - Canopy height
   - Canopy base height
   - Ladder fuel density



More specifically, the above datasets will be used to create maps of the following metrics for all formations with tree or shrub cover:

- Near surface fuel height and cover (%)
- Elevated fuel height and cover (%)
- Canopy height and cover (%)

Data provided in the form of ESRI compatible GIS layers that can be incorporated into NSW RFS "Predicted Forest and Woodland Fuel Load layer" and as inputs to their Fire Behaviour Models (Phoenix and Spark), all subject to 1) Salo receiving such specifications from NSW RFS and 2) the mutual agreement of RFS and Salo on such specifications.



2. Report documenting the data, its accuracy compared to airborne lidar, and a comparison to existing maps of above metrics (where possible).
3. Project scope and plan for expanding the modelling to all of NSW with a cadence of one month, quarterly and half yearly

Intellectual Property:

Development: Intellectual property ("IP") in the form of data, data processing technology, software systems, and other IP customary in technology and software development will be produced by Salo Sciences in connection with this Project. The data outputs produced will embody the majority of the deliverables, along with project reporting, described above. No new capital infrastructure will be required to complete the Project. Additional IP required for the Project falls into two categories: 1) Existing Salo Sciences proprietary IP and 2) 3rd-party data and tools that are currently or will be licensed, including Google Cloud Platform computing resources, and other backend technology services.

- Ownership: Salo Sciences will retain ownership of all new IP developed in connection with the Project, provided that it will transfer ownership or provide a third party of Minderoo's choosing with a perpetual and permissive license to the Data Deliverables in the event the Project does not progress to Phase 2 for any reason.
- Phase 1 Licensing: Salo Sciences will license the Data Deliverables under a perpetual permissive license for all non-commercial uses (i.e. use by government, research, and non-profit users) to encourage the widest possible evaluation and adoption in the target end user groups. This licensing scheme will simplify the legal and monitoring burdens in the pilot phase of the Project for both Salo and the evaluators/users.
- Phase 2 Licensing: If the Project progresses to Phase 2, licensing will largely depend on the revenue/funding source at that point and their desires—so, attempting to pin down specifics now is difficult. There are three potential revenue/funding streams:
    1. *RFS/Government*: In the event RFS, the Federal government, State government(s) or some combination of these bodies funds the full-scale resource via procurement, licensing will be determined by their scope of needs, length of commitment, funding level, and openness to Salo commercializing other use cases to support sustainability.
    2. *Minderoo*: If Minderoo funds Phase 2 in whole or part in combination with the others, Licensing scope will be influenced by its goals for access. Salo is open to permissive licensing for non-

commercial uses *a la* the California Forest Observatory, provided the funding amount and protected commercial opportunities support long-term sustainability.

3. *Commercial Partner*: Advance and early stage commercial deals may provide revenue to support Phase 2 scale in exchange for preferential pricing and licensing terms. In this case, we would negotiate commercial license terms directly with them while securing non-commercial use rights via other revenue sources. This is likely the most complicated option, but certainly feasible and analogous to other technology-focused public-private partnerships.

Reporting

Two-week development cycle review meetings over Teams between Minderoo and Salo (NSW RFS optional).

Report	**Reporting Period**	**Responsible Organisation**	**Due Date**
Progress Report	Week 1 - 4	Salo Sciences	Week 5
Evaluation report on project outputs	Week 1-11	NSW RFS	Week 11
Reporting provided on; ● Accuracy produced ● Final Narrative Report & Financial Acquittal ● Preliminary report on scaling to all of NSW, additional jurisdictions	Entire project period	Salo Sciences	Week 13

Beneficiaries

We designed the Forest Observatory to support the work of four primary groups, who are expected to benefit from deploying this system in NSW:

- **Land managers, scientists & foresters**: people responsible for measuring, monitoring & managing forested lands, often working to restore resilience to bushfire and climate change, and keep communities safe from bushfire.
- **Firestarters**: government personnel working to update the state's prescribed burn planning, implementations and public communications systems.
- **Emergency services**: personnel who anticipate and respond to bushfire-related emergency events, including evacuation planning, emergency response, post-fire risk & recovery monitoring.
- **Risk management**: teams who evaluate and manage risk, working to quantitatively predict the likelihood and intensity of bushfires.

Potential use cases in NSW (see Appendix B for visual examples from California):

- Improved bushfire modelling using more accurate, higher resolution, and up-to-date fuels maps
- Defensible space inspection prioritization and monitoring using high resolution maps of vegetation cover and height
- Fuels treatment and forest restoration planning, prioritization, and monitoring

- Post-bushfire vegetation impact assessment
- Harvest monitoring: both clear-cut and selection (thinning) harvest can be detected and quantified with high-resolution vegetation height maps
- Monitoring risk of damage to infrastructure or bushfire ignition from potential hazard trees

Expected beneficiaries in NSW include:

- Rural Fire Service (RFS)
- Dept. of Planning, Industry, and Environment (DPIE)
- National Parks & Wildlife Service
- NSW Environmental Protection Authority
- Biodiversity Conservation Trust
- Nature Conservation Council of NSW
- CSIRO/Data61
- Natural Hazards Research Australia
- NSW State Emergency Service
- Resilience NSW
- Forest Corporation
- NSW Fire & Emergency
- Local governments within NSW

Economics:

- Using the lowest cost airborne LiDAR collection rate we've seen (~$400/km^2) flying 70,000 km^2 would cost at least $25M USD, and just provides one snapshot in time. This doesn't take into account the difficulty and time to process and operationalize the raw lidar data for use in creating input data for fuels maps.
- Current fuel map creation and updates are manual, expert-driven processes, requiring significantly more staff time and resources that could be unlocked for other purposes.
- Using more accurate and highly resolved maps of vegetation fuels in bushfire spread models will produce more realistic predictions of fire behavior. Whether used operationally to direct initial and extended attack on an active bushfire or to produce maps of potential hazard to plan fuels treatments to mitigate bushfire risk, indirect costs savings from avoided damages to assets, infrastructure, and ecosystem service (e.g., watershed health) could be substantial.

What does success look like?

The Phase 1 pilot is a proof-of-concept phase, where the project partners demonstrate viability and highlight the opportunities to improve bushfire prediction and response. Key improvement areas in the vegetation fuels maps we expect to deliver on are spatial resolution, currency and accuracy.

Success of the project will mean delivering on the outputs laid out earlier;

1. Demonstrate proof of concept of 10x10m resolution maps of vegetation fuels datasets covering the test regions in NSW (provided by Salo)
2. Evaluation conducted by NSW RFS of the vegetation fuels pilot maps against their current maps confirms that marked improvement across spatial resolution, currency and accuracy for the vegetation fuel mapping. This process includes using NSW RFS conducting field work or SPOT imagery from Spatial Services to validate the calculations made by the NSW Forest Observatory Tool and observations sighted in real world
3. Report documenting the data produced, its accuracy compared to airborne lidar, and a comparison to existing maps of above metrics (provided by Salo)
4. Understanding of resources and time required to scale the project (provided by Salo)

5. The data outputs of the NSW Forest Observatory Tool can be directly put into the Fire Behaviour Models (Phoenix and Spark) used by NSW RFS without any manipulation required
6. NSW RFS and/or other key users of Spark demonstrate intent to utilize these data sets to improve their operations on a go-forward basis across priority areas of the state.

Collaboration

The Forest Observatory is expanding beyond California thanks to the support of other philanthropic and industry funders. This includes the expansion to the western United States, increasing coverage from 1 to 11 states in the coming year, driven by at least 3 new philanthropies in addition to the 3 that provided the initial funding.

Several state and federal agencies are active users of the data in California, and colleagues from the US Forest Service are actively advising on how to identify government funding opportunities to support the long-term viability of public access to Forest Observatory data. Collaboration and funding from multiple agencies were success criteria from previous engagements and will be key to encouraging buy-in from counterparts in Australian fire science and response.

Since the project outputs are primarily maps of vegetation fuel type and vegetation structure, there are many opportunities for collaboration with other Minderoo Foundation initiatives. The Healthy Landscapes Initiative seeks to build resilience in the most vulnerable communities, and high resolution, up-to-date vegetation data can help guide community risk assessments and serve as a guide to develop risk mitigation projects. The Fire Shield Initiative seeks to rapidly respond to and suppress bushfires before they become catastrophic, and up-to-date fuels data, combined with local weather and infrastructure data, will be critical inputs for evaluating which fires should be most aggressively contained.

The goal of this project is to develop a dataset that can plug-and-play with existing bushfire simulation tools and risk management platforms, facilitating open, data-driven dialogue between the diverse array of stakeholders who collaborate on bushfire planning and response.

Project Risks

We do not anticipate any regulatory or capacity risks in developing and delivering the pilot system.

Technical risk:
The Forest Observatory's technical system has only been deployed in California for mapping US-based wildland fuel patterns; translating this work to another area and a different set of fuel classes is a technical risk. However, we believe this is mitigated by the modelling approach we have developed, which uses 1) satellite data that are globally consistent and accessible and 2) airborne LiDAR data, which can be processed using the same workflows we developed for the US. Regarding the fuel class typologies, Salo Sciences has reviewed technical documentation of the Keith models of vegetation formations that drive contemporary fire simulation models and are confident that, with some expert guidance from NSW RFS, they can properly reproduce the classification system.

Timeline risk:
The expected delivery of data to NSW RFS is very short. Delivering the project outcomes will require:

- Acquiring and co-registering large volumes of satellite imagery from multiple vendors
- Downloading, processing, and co-registering large volumes of airborne LiDAR data
- Developing new deep learning models, or extending existing ones from California, to develop the LiDAR-satellite relationship to create continuous maps of vegetation structure across the pilot area

- Develop a novel, high resolution approach to classifying existing vegetation formations
- Merge these metrics of vegetation structure with vegetation formation maps

These are difficult tasks under normal operating conditions and will require major innovation and iteration among partners to achieve them on a short timeline.