Australian Government

Australian Centre for International Agricultural Research

Final report

Small research and development activity

project	**Trial of techniques to empower community and government monitoring and evaluation of Indonesian peatland restoration**
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1 Acknowledgments

This research could not have been completed without the generous support of Campbell Scientific, and the University of Western Australia who made available the critical equipment and data logging capability to make the measurements of carbon, water and methane emissions from the peat site. We are also extremely grateful to our partners on the ground. BKSDA, Central Kalimantan Provincial Office, (Conservation Agency, Ministry of Forestry) and the Camat of the Mantangai Subdistrict has supported this work to proceed, with the Village Head of Mantangai and Army Office in Mantangai allowed us to install equipment on their land and helped us engage with the wider local community. We finally thank the field teams for collecting the data in such an extreme environment.

2 Executive summary

Peatland restoration is a national priority for Indonesia, with potential threefold benefits of reducing greenhouse gas emissions from degraded peatlands, improving air quality by eliminating unwanted peat fires and improving food security. This project trialled an eddy covariance flux tower and a network of Chameleon soil water sensors in a tropical peatswamp forest area undergoing restoration.

This trial found that both eddy covariance flux towers and Chameleon soil water sensor networks are technically feasible approaches to monitoring the water and carbon dynamics of peatlands undergoing restoration. Local research and field team members successfully operated these systems, with intensive initial expert training followed by ongoing remote advice. Scientific capacity building has been a highlight of this project. Engagement with local community and government stakeholders has been positive, with strong interest and support at both provincial and village level.

This initial study suggests that tropical peatland restoration can feasibly be directly monitored at landscape scale. The two techniques trialled have a complementarity than can provide a real-time and scientifically rigorous evaluation of national greenhouse gas and fire mitigation efforts. Our results demonstrate that Indonesia has the scientific capacity to take peatland restoration beyond installation of infrastructure to monitoring and evaluation of success.

In practise, there remains significant work to be done to fully utilise the technical capability of eddy covariance flux towers and Chameleon sensor networks as sources of data to inform decision support tools that empower government and communities to sustainably manage peatland restoration. The Indonesians who now successfully operate the trial system, as well as the local and provincial government stakeholders who have so enthusiastically supported this initial trial, will be critical actors in this next phase of transforming data into user-centric knowledge products.

The key benefit resulting from this project is the establishment of a successful and robust transdisciplinary partnership. This research team, the strong relationships with stakeholders and integration into wider scientific, policy and practice networks, which was born of fire and matured over COVID, lays the foundations for high impact, paradigm changing monitoring and evaluation of peatland restoration. The benefits for climate and food security will be felt nationally as well as internationally.

3 Background

This project directly addresses ACIAR's high level objective of "finding ways to better manage natural resources and more effective responses to climate change". Restoring degraded peatlands is likely to make a major contribution to Indonesia's plan to meet its Nationally Determined Contributions. Rewetting these carbon-rich soils will slow their release of carbon dioxide and methane to the atmosphere and, in the long term, may enable them to regain their function as carbon sinks, a process that can accurately be quantified using the eddy covariance methodology as was adopted in this project. Methane emissions will be a significant component of the greenhouse emissions profile from degraded peatlands. This project will trial techniques to monitor restoration success, enabling cost efficient and effective roll out of the best practise restoration over Indonesia's remaining 7M ha of degraded, regularly burning peatlands over the 2020s. A contribution to Indonesia's ability to monitor and reduce its greenhouse gas footprint via peat forest management and restoration has national and international benefit. Further, the Chameleon sensor could play a role in Indonesia's fire prevention strategy, as part of an early warning system for peat fires.

The project also addresses ACIAR's high level objective of "food security and poverty reduction". The revegetation component of peatland restoration can include water-loving food plants. The Chameleon Sensor is a robust sensor system to monitor soil moisture stress levels that has potential to empower villagers in restored peatlands to monitor restoration, diversifying their income by collecting valuable data for the Government of Indonesia, and also to successfully produce food crops.

4 Objectives

The goal of the project was to empower local communities and government agencies to monitor and evaluate the success of peatland restoration, by undertaking a trial techniques that have potential application in tropical peatland restoration. We trialled two novel tools, specifically suited to community and government stakeholder audiences. The two techniques are eddy covariance flux towers and Chameleon sensors.

The first Objective was to install and trial an eddy covariance flux tower in a degraded tropical peat swamp forest. Eddy covariance measures the flux of water, carbon dioxide and methane in real time at catchment scale. Fluxes of CO_2 and CH_4 will account for the majority of the greenhouse gas emissions from peatlands. Restoration aims to rewet the peat soil, reduce fire risk and revegetate the degraded peat surface, as well as revitalising local livelihoods. The eddy covariance (EC) method simultaneously measures water (evapotranspiration) and carbon fluxes, tracking the changes in hydrology and vegetation growth (carbon sequestration) occurring in a peat catchment. This project trialled the use of an eddy covariance system in the harsh tropical environment of a seasonally flooded degraded peatland to monitor the dynamics of seasonal fluxes and assess it's the systems suitability for monitoring peatland restoration. The technique proved successful, but further research is required to realise the potential of these methods to empower Indonesian government agencies to monitor and assess the progress of restoration works in the short and medium term.

The second Objective was to install and trial a series of low-cost soil moisture sensor (Chameleon sensors) at the same degraded tropical peat swamp forest within the footprint of the EC flux tower. A second set of sensors was also installed in the nearby village of Mantangai. The Chameleon has a wifi reader developed with ACIAR support to empower smallholder farmers in Africa to apply irrigation water efficiently. This project trialled an adaptation of these Chameleon sensors to monitor soil water content in degraded peatland sediment. The Chameleon's simple, colour-based interface is specifically designed to empower community users. Furthermore, the individual sensors are connected by mobile phone download to an online data base.

The Chameleon sensor has been successfully adapted to peatland conditions, and now this technology could be used to empower communities in two ways. Firstly, smallholders can use the Chameleon sensor to inform their regulation of soil water content in order to successfully grow water-loving food plants for household consumption and sale. Secondly, government agencies could incorporate the Chameleon sensor into their restoration monitoring "best management practise" and employ communities in ongoing monitoring and peat fire prevention.

Linking the two technologies (eddy covariance, Chameleon sensor) provides a powerful approach to link the hydrological status of the peat, regrowth and greenhouse gas emissions.

5 Methodology

5.1 Location: where was the work done?

This research focused on degraded tropical peat swamp forest in Block A of the Ex Mega Rice Project, near the Mantangai Village in Central Kalimantan, Indonesia. The installation of the EC tower and Chameleons occurred towards the centre of the peat dome and at the peat dome edge, the village. Chameleons were also installed at the University of Palanga Raya campus and Borneo Orangutan Survival Foundation (BOSF) office in Palangka Raya and at RMIT University in Melbourne Australia, for education and capacity building purposes. The BOSF leads engagement with Government Agencies at the Central Kalimantan Provincial, and Kapuas District levels.

Capacity building was a core focus of this project and this activity occurred both remotely, via our regular team Zoom meetings and active email and What'sApp communications, as well as in person. Four Indonesian researchers from BOSF and UPR joined Australian researchers at the Joint Asiaflux-Ozflux Data Processing Workshop and Conference in Darwin in 2018. This was a great opportunity for many of the team to meet for the first time, as well as a concentrated introduction to the theory and data analysis of the EC technique. A smaller workshop occurred in Canberra to build the team's capacity around the theory and technical operations of the Chameleon sensor, April 2019.

5.2 Strategy and Techniques: how was the work done?

Phase I - Logistics, permits, socialisation

This ambitious Small Research Activity aimed to trial two novel and technically complex measurement approaches in a remote tropical peat swamp forest. Core valuable equipment was lent to the project and dozens of other components were purchased with project funds. As such, the initial phase of the research centred around logistics; shipping equipment between USA, Australia and Indonesia. Trust-worthy import-export agents had to be engaged in order to ensure that equipment could be legally returned to the owners at the completion of the research. A site location was selected by the team, balancing micrometeorological requirements of the EC technique, site access, restoration works current and planned, complementarity with BOSF's ongoing research and monitoring of fire, vegetation and hydrology and finally, government permission.

BOSF Mawas works closely with all its Government partners and stakeholders, providing monthly reports and updates on the progress of all activities and projects in its area. One key partner is the BKSDA's (Conservation Agency, Ministry of Forestry's) Provincial Government Office. They supported the project's objectives and agreed we could establish the project on the area of the protected forest peat dome which they manage. We held a Kick-Off and Socialisation Workshop in the BKSDA office, with all stakeholders, before field activities began, to explain and discuss all aspects of the project, its activities and intended outcomes and impacts.

Chameleons were located both towards the centre of the peat dome, in a degraded forest area, and in the Mantangai village at the edge of the dome, and thus additional socialisation activities were carried out to engage with the local community and village government to ensure the project was supported and that the site instruments could be installed in safe and strategic locations.

Phase I was also a period of intense capacity building and internal socialisation within the project team. The 18-person team is drawn from Indonesia staff of BOSF, University of Palanga Raya, RMIT, UWA, CSIRO/Solutech and CDU. Many of the team had not met or worked together before and the project included new and complex elements for everyone. Learning during this phase was exponential; with team members progressing from beginner to novice on topics such as tropical peat swamp forest ecology and historical land management, eddy covariance flux measurements, project management, the physics and chemistry of soil water content measurement.

Phase II - Installation, SOP development, trouble shooting

The second phase of the project centred around installing the instruments in the degraded tropical peat swamp forest that the project aimed to trial. As a trial of the feasibility of these techniques, the project team was literally breaking new ground with every step. Wetlands are challenging environments for people and scientific equipment. Fortunately, BOSF staff have decades of on-ground, practical experience working in this ecosystem and their collective wisdom and local knowledge was essential in the planning of the flux tower location, material, sizing, logistics and shipping, transport and site access and site security. This was fundamental to the success of this critical phase of the project.

The EC system relies on reliable power supply and given the site is remote, additional planning was required to design and implement of solar power supply. This was designed and constructed by the BOSF team, together with support and field inputs from a local construction business from Mantangai, and a local electricity company from Palangka Raya. The result was an 8 m high wooden tower constructed from local timber, a durable material that can withstand the acidic peat and periodic flooding and drying, together with solar-powered 24-hr electricity supply plus storage capacity, with equipment imported from Germany via Java.

Figure 1 The project team onsite during the flux tower and Chameleon sensor installation, July 2019. The flux tower consists of an 8 m platform with gas analysers and wind speed sensors mounted on the upper platform. A 110V AC / 12 V DC solar system provides reliable power the system.

A team of three-full time staff members was employed through BOSF Mawas to become the Security and Field Research Team for the EC Tower and Chameleons. All three were from the Mantangai Village.

Two field campaigns saw the installation of the EC equipment and the Chameleons. In both cases, due to the unique and remote environment for installation, considerable time was invested into correct design layout, orientation, and training and capacity building of the team to use and maintain the equipment. In both cases detailed bilingual field SOPs were developed to facilitate the field teams to operate consistently and accurately.

Access to a 24-hr internet connection proved the most challenging aspect to construction, and is yet to be achieved. Planning involved installing telemetry to enable remote data collection with data provided to the team online. This was not possible in the available field time and a periodic data upload schedule was implement by the BOSF team. Communication at the site will be a component of the next phase of the project.

The field team use a roaming modem to manually connect the Chameleon data storage arrays to the internet once a week, at which point the data becomes available and viewable on the VIA Farm website. The daily data size generated by the EC system requires large capacity memory storage cards which are swapped fortnightly with data uploaded to a cloud server. Site access is required to manually collect memory cards which are then transported to base via a two-hour boat journey followed by a five-hour road trip. Data are then copied, backed up and manually uploaded to the secure CloudStor file storage and syncing service. Empty cards are then be returned to the field for re-use. EC tower data are uploaded minimally once per month, facilitated by the regular activities of the field team moving between town and field.

Phase III Data analysis, maintenance, succession planning

A 24-hour, year-round security team was advised at the start of the project, both by BOSF based on knowledge of the local area and UPR-CIMTROP based on experience managing flux towers at other locations. The advantage to this system is the tower can also double as a fire look-out post and weather station, and daily tower and equipment maintenance is possible. Consequently, the field teams follow SOPs for daily activities of equipment and area security, safety and maintenance, with daily updates via WhatsApp work groups.

The initiation of the Covid-19 pandemic coincided with end of the financially-funded period for the data collection in the field with BOSF. However, with the developing plan for Phase II of the project, the security or de-installation issues associated with the field equipment, and the desire to maintain a trained and skilled field team, the project team approached ACIAR and was granted additional funding for this transition period. With all the installation activities implemented, the field team being able to work semi-autonomously within the SOP guidelines, and with no additional field or community activities scheduled until Phase II, the running costs of the project were relatively low and able to proceed on the small additional budget. The advantage of a semi-autonomous field team with largely remote supervision, after investing the time to enhance capacity and develop SOPs, was again an advantage during the pandemic situation, when travel from the city to the field became challenging. The field team was able to proceed locally and data uploading was managed to accommodate the new distancing restrictions, but with no impact to data collection or storage.

The Chameleon data is stored within, and is visually viewable and downloadable from the VIA Farm website, with excellent technical support from the CSIRO team. Initial data download and analysis has begun.

The project has completed the three technical reports for the SRA, and these were developed as a team, with all partner institutes contributing both knowledge and findings.

We are excited to begin the second SRA or Phase II of this project, where we will continue to grow the database of field collected moisture and flux data and further develop the community engagement aspects of the project, focusing on local and government stakeholders of the region and application of the method and data being collected. We also look forward to how this work may be applicable to meeting ACIAR's wider peatland research impacts and direction, and align with the goals and impacts of the larger Indonesian Peatlands Project over the coming years.

5.3 Partners and Stakeholders: who was involved in the work?

This research was led by RMIT University in Australia and Borneo Orangutan Survival Foundation in Indonesia. The research team partners that made this project possible were the Universities of Western Australia and Palangka Raya, Charles Darwin University and Solutech. CSIRO contributed guidance and advice. Campbell Scientific (USA) played a key enabling role as industry partner, lending the core EC equipment.

Stakeholders who played an active role in this research include the Natural Resources Conservation Agency of Central Kalimantan, Mantangai Village Head and Mantangai Army Base. Their enthusiasm and co-operation in facilitating installation of our equipment has been critical to the project's success and all parties await further engagement in designing a peat-specific user interface for the data we are collecting, in SLaM2020118.

Figure 1: a) Chameleon poster installed out the front of the BOSF Mantangai Office, adjacent to the installed Chameleon sensor, b) Chameleon sensor and poster installation at the army office in Mantangai.

A B

Figure 2. The Flux Tower workshop in the Natural Resources Conservation Agency of Central Kalimantan office. (A) Photo group of all the attendees; (B) presentation about the eddy covariance method by Dr. Fengky F. Adji, SP., MP., PhD from CIMTROP-UPR

6 Achievements against Activities and Outputs/Milestones

The achievements of this project are impressive in light of the modest funding allocation, challenging physical and socio-political conditions, and more recently, the Covid-19 pandemic. More than 12 months of data has been collected from both the eddy covariance system and the Chameleon sensor network, in a key peatland restoration location in a remote area of the Ex Mega Rice Project (Phase 1 Activity fully achieved). The technical feasibility of the two techniques, implemented in this landscape, has now been rigorously assessed and reported. Standard Operating Procedures have been developed for field maintenance of the instruments, collection, downloading and uploading of data enabling local people to operate and use both techniques.

Communication with the local community and government stakeholders has been a strength of this project, as described above. However, due to the timing of installation of equipment and then COVID-19 related restrictions, this communication has centred around introducing the techniques and concepts. Communication of results via face to face workshops, village meetings and field demonstrations had been planned in great detail, with tentative invitations and dates extended in early 2020 for April. This aspect of the project has been put on hold and stakeholders remain engaged and keen to participate when conditions allow. As such, the Phase 2 Activity has been only partially completed. The achievements of the planned third phase of activity have been modest, with the project team engaging with national level efforts to monitor and evaluate peatland restoration success. Examples include participation in CIFOR's online Workshop Series Exploring Criteria and Indicators for Tropical Peatland Restoration, FAO's webinar on research techniques for monitoring tropical peatland carbon emissions remotely, and the Ministry of Forestry's webinar on carbon emission calculation for tropical peat forests. With a current focus on water table monitoring and remote sensing, the continuation of this project has a significant contribution to make in this space.

Recommendations around use of eddy covariance and Chameleon sensors for peatland restoration monitoring and evaluation are yet to be drafted (Phase 3 Activity partially achieved).

For reference, the planned activities from the initial Project Proposal are listed here:

Planned Activities

The first Phase of the project will collect 12 months of data from each technique in a degraded peatland site, co-located with the work of FST/2016/144. By testing these two approaches in a degraded peatland slated for imminent restoration, this trial will collect valuable baseline data upon which to evaluate the success of future restoration works.

The second Phase of the project will assess the technical feasibility as well as accessibility to community and government stakeholders. Communication of results and alpha testing of concepts with a select group of engaged community members and government officials will be conducted, via workshops, meetings and field demonstrations over a 6 month period.

The third Phase of the project will explore further requirements needed to implement eddy covariance and Chameleon sensors more widely. Recommendations will be drafted, in close consultation with government agencies

Outputs and Milestones

Three technical reports comprise the formal outputs and milestones for this project. A fourth output, a draft journal article on the feasibility of the eddy covariance technique and Chameleon sensors for peatland condition monitoring and research, was planned as an Annex to this final report. Due to the project rescoping in response to COVID-19 restrictions, this fourth output has been delayed. A skeleton for this journal article, targeting the journal Environmental Monitoring and Assessment, is attached as an Annex to this final report.

Technical Report 1

An initial assessment of feasibility of using eddy covariance techniques to quantify evolution of water, CO_2 and CH_4 to the atmosphere from peatlands with the precision required to identify changes associated with peat rewetting

Technical Report 2

An initial assessment of feasibility of using Chameleon sensors to quantify changes in water content in peatlands with the precision required to identify changes associated with peat rewetting

Technical Report 3

A preliminary estimation of water, CO_2 and CH_4 emissions from rewetted peatland, including estimation of the uncertainties, and recommendations for improving accuracy/precision

7 Key Results and Discussion

The key results from this project are:

1) Chameleon sensors can operate in tropical peatland soils

2) Chameleon sensor water content data is amenable to both scientific ecosystem monitoring and ecohydrological assessment as well as community engagement.

3) The eddy covariance technique can be rapidly learnt and successfully operated by local Indonesian NGO and university researchers, without prior micrometeorological disciplinary expertise.

4) Interest and engagement from Mantangai community and local government, as well as provincial government agencies, is high, providing a solid foundation for co-creation of peatland condition monitoring decision support tools with end users.

5) Tools to monitor and evaluate peatland restoration are a hot topic, of great interest to the Government of Indonesia as the first term of the BRG comes to an end and evaluation of restoration efforts gains attention.

This project was designed as a trial of techniques to empower community and government monitoring and evaluation of peatland restoration. The Chameleon sensor and eddy covariance approaches to measuring water and carbon fluxes work, in tropical peatlands undergoing restoration. We have shown that these sensor systems can be installed and operated in this regenerating peat landscape and with support, local technical and research staff can matain the systems and manage the data generated. Considerable capacity has been built within the 2 years of the project.

Technical Report 3 describes preliminary water and carbon flux data and analysis (see links to the publicly available Chameleon sensor data, Appendix). In this sense, the techniques are sound and applicable in this context. However, the second part of the project, to empower community and government monitoring of peatland restoration, is more complex and there is significant body of work to transition from data collection and maintenance to quantification of typical annual GHG emissions profile from a degraded peat site. .

Figure 3, below, is a birthday card for the flux tower that BOSF staff created to share with local and provincial government stakeholders as a promotional tool. Note that several of the people featured in the birthday card are the local field team members who are from Mantangai. Equally, when the Chameleons were installed in the grounds of the Village Head and Army Office, there was much community interest. The participants, stakeholders and others who had stopped to watch and listen were all shown how to access the Via Farm data and monitor the colour coded soil dryness indicator charts. This website is still often visited by community members with comments being passed on the findings, and our team being warned when the batteries are becoming low and need recharging (as shown on the website)! The sense of ownership, as well as genuine interest-based engagement with stakeholders, demonstrated in this unscheduled knowledge product development and distribution, evidences the success of this project in collaborative research practice and capacity building. It also demonstrates the strong foundations that have been laid in building relationships with community and local and provincial government stakeholders.

24TH JULY 2019 - 24TH JULY 2020

FLUX TOWER 1 YEAR DATA COLLECTION

SLaM/2018/122

Trial of eddy covariance flux towers and Chameleon sensors for evaluating peatland restoration in Indonesia

Partners & Collaborators

RMIT, BOS, CIMTROP, The University of Western Australia, Charles Darwin University, VIA, CSIRO

Donors

ACIAR, Campbell Scientific

8 Impacts

This SRA attempted and succeeded to implement two complex technologies into a challenging environment. As such, much of this first SRA was invested in planning, designing, surveying, engaging, requesting and attaining permissions and training. As such, future outputs and subsequent impacts which we look forward to from this project are still in development, but now based upon a strong foundation. Equally, some strong scientific engagement, capacity building and environmental impacts have already been achieved and are described below.

8.1 Scientific impacts

In additional to the three ACIAR technical reports and the journal article currently under draft which summarises how to go about implementing this technology in tropical peatlands, we have also:

- Written:
  - Methodological design and layout considerations and rationale reports for:
    - Construction of the EC flux tower
    - Installation of the Chameleon sensors
  - Bilingual SOPs in:
    - Daily and weekly activities for security, maintenance, data management and storage of the EC flux tower and Chameleon equipment in the field
    - Data management SOP for the whole project
    - Data-logger and Multiplexor trouble shooter field SOP
    - Raingauge upkeep field SOP
    - Chameleon installation and data download SOP (adapted from the CSIRO publicly available version)
- Presented posters on the project at two international conferences:
  - Sherly Manjin, Samantha Grover, Amanda Sinclair, Steve Zeglin, Laura Graham, Andri Thomas, Ramadhan, Zafrullah Damanik, Nina Yulianti, Fengky F. Adji, Lindsay Hutley, Jason Beringer, Ivan Bogoev (2018) Eddy covariance as a tool for monitoring tropical peatland restoration at a catchment scale. Tropical Peat Ecosystem and Restoration Conference, Palangka Raya, Indonesia, 21-22 November 2018
  - Amanda Sinclair, Steve Zeglin, Laura Graham, Andri Thomas, Ramadhan, Sherly Manjin, Zafrullah Damanik, Nina Yulianti, Fengky F. Adji, Lindsay Hutley, Jason Beringer, Ivan Bogoev,Samantha Grover (2018) Eddy covariance as a tool for monitoring tropical peatland restoration at a catchment scale. Asia Flux – Oz Flux Conference and Technical Workshop, Darwin, Australia, 20-25th August 2018
- Published a summary of the project in the eTERN newsletter

8.2 Capacity impacts

As a relatively new science to the Indonesian team members, there has been multiple opportunities to enhance the capacity of the in-country partners of this project:

- Two team members from UPR and two from BOSF were able to travel to Australia to attend the Asia Flux – Oz Flux Conference and Technical Workshop held Darwin, 20-25th August 2018
- During the installation of the EC tower and the training in the use of the Chameleon sensors, when the Australian partner scientists were all the in the field together with the UPR and BOSF teams there was much opportunity for the increased knowledge exchange and understanding regarding both the methods

and equipment and the ecology of the field site. Indeed, the UPR team brought four undergraduate students on this trip as well, to facilitate enhanced training.

- The Environmental Monitoring and Research Team, BOSF Mawas (composed of 10 Indonesian team members, 4 of which are from Mantangai) now have a greater understanding and could replicate with greater ease the installation, running and data management of the EC tower and the Chameleon experiment.
- All the stakeholders and partners in this project, including UPR, BOSF, BKSDA, and Mantangai village participants now have a greater understanding and appreciation of the use and application of these two novel technologies for monitoring tropical peatland ecosystem health

8.3 Community impacts

8.3.1 Economic impacts

Currently the main economic impact to this project has been the additional full-time, year-long employment for three local community members. Furthermore, there has been local contributions to business through sourcing sustainable timber from local suppliers, with a local construction company, and various small businesses supplying logistics for the project.

8.3.2 Social impacts

There has been positive impact and progress in local community empowerment and feelings of ownership with regard to project activities, through the ability to access data directly and engage directly with the field team and researchers working on the ground. We hope to continue, prioritise and build upon this foundation in the second SRA of this project.

8.4 Environmental impacts

The focus on community engagement, participation and accessibility to collected data has led to numerous interested discussions and exchanges regarding the uses and application of the data, the issues and indicators associated with peat fire and haze risk, the approaches and evaluation of rewetting, and has overall led to a more open and increased discussion regarding local environmental issues and conditions within the village of Mantangai.

The tower has also served as a useful and convenient fire look-out post. Tropical peatlands are flat landscapes, and, in addition to the lost forest cover, the 8 m high tower affords visibility for smoke plumes for kilometres in all directions. The team conduct maintenance and security checks on the sensor systems twice daily, this effort has also doubled as an extremely helpful fire observations station through the dry season. This is especially significant as the tower is placed in highly degraded peatlands which frequently burns, and it is also in the vicinity of BOSF' reforestation activities which require extra vigilance.

Furthermore, as the BOSF team and participating community members become more adept at reading the chameleon data uploads on the Via Farm site, this data has started to be applied by BOSF as early warnings for fire risk. Although greater analysis and investigation regarding the prediction ability and key dryness levels etc. still requires future work, this equipment already has started to serve a role, with, for example, the BOSF Reforestation team and the local Army members as a rough-and-ready guide for when to switch to extra vigilance and care regarding fire risk.

8.5 Policy impacts

BOSF always prioritises the enhancement institutional capacity and engaging with government stakeholders in all its projects. In addition to monthly reporting, BOSF, UPR and BKSDA worked in partnership to host the Kick-Off Workshop in the BKSDA offices, to which other related government institutes were also invited. As the project moves forwards this engagement, relationship and foundation will be key to instigating policy level change.

9 Conclusions and recommendations

9.1 Conclusions

In conclusion, the trial of techniques to empower community and government monitoring and evaluation of peatland restoration has demonstrated that Chameleon sensors and the eddy covariance approach are technically feasible and can be used to monitor peatland restoration. Positive foundational relationships have been developed with local community and government stakeholders and the techniques have gained their sustained interest over the initial 2-year trial. Further work remains to explore user requirements prior to development of an ecohydrologically data driven peatland condition decision support tool to support peatland fire suppression and restoration. Evaluation of peatland restoration success has become a priority for the Government of Indonesia over the 2-year lifetime of this project and requires further multi-site and multi-criteria primary research.

9.2 Recommendations

Efforts to empower communities and government to remotely and accurately monitor and evaluate peatland restoration will be best served by integrating environmental data on peatland water and carbon fluxes with local decision-making structures. Three specific recommendations from this project are to:

1. Continue monitoring water, carbon dioxide and methane fluxes as a function of climate and hydrological conditions of a degraded peat forest using the eddy covariance flux tower and Chameleon sensor network installed in this project.
2. Apply flux corrections to all data to enable annual GHG emissions to be made, linking changes in fluxes with rainfall, water table height and soil moisture data.
3. Collaborate with community and local government stakeholders to socialise this approach, share initial data and explore uses and formats, via a series of workshops
4. Identify the knowledge and communication needs of community and government stakeholders for monitoring peatland restoration, to inform future design of a decision support tool

This will require additional social science expertise to complement the disciplinary and technical expertise of the current team. Further, it is critical that biophysical researchers engage with current policy discussions around peatland restoration at a national level in Indonesia. This project team has a valuable contribution to make in sharing understanding of the linked carbon and water fluxes of peatlands undergoing restoration, in light of the current single hydrological criteria of a static watertable depth of 40 cm for peatland restoration used in government policy at present.

Evaluation of peatland restoration success will require transdisciplinary research that engages strategically with local communities and all levels of government and should take advantage of international efforts in this space such as the Global Peatlands Initiative, the International Tropical Peat Centre and the Centre for International Forestry Research’s Sustainable Wetlands Adaptation and Mitigation Program.

10 References

10.1 References cited in report

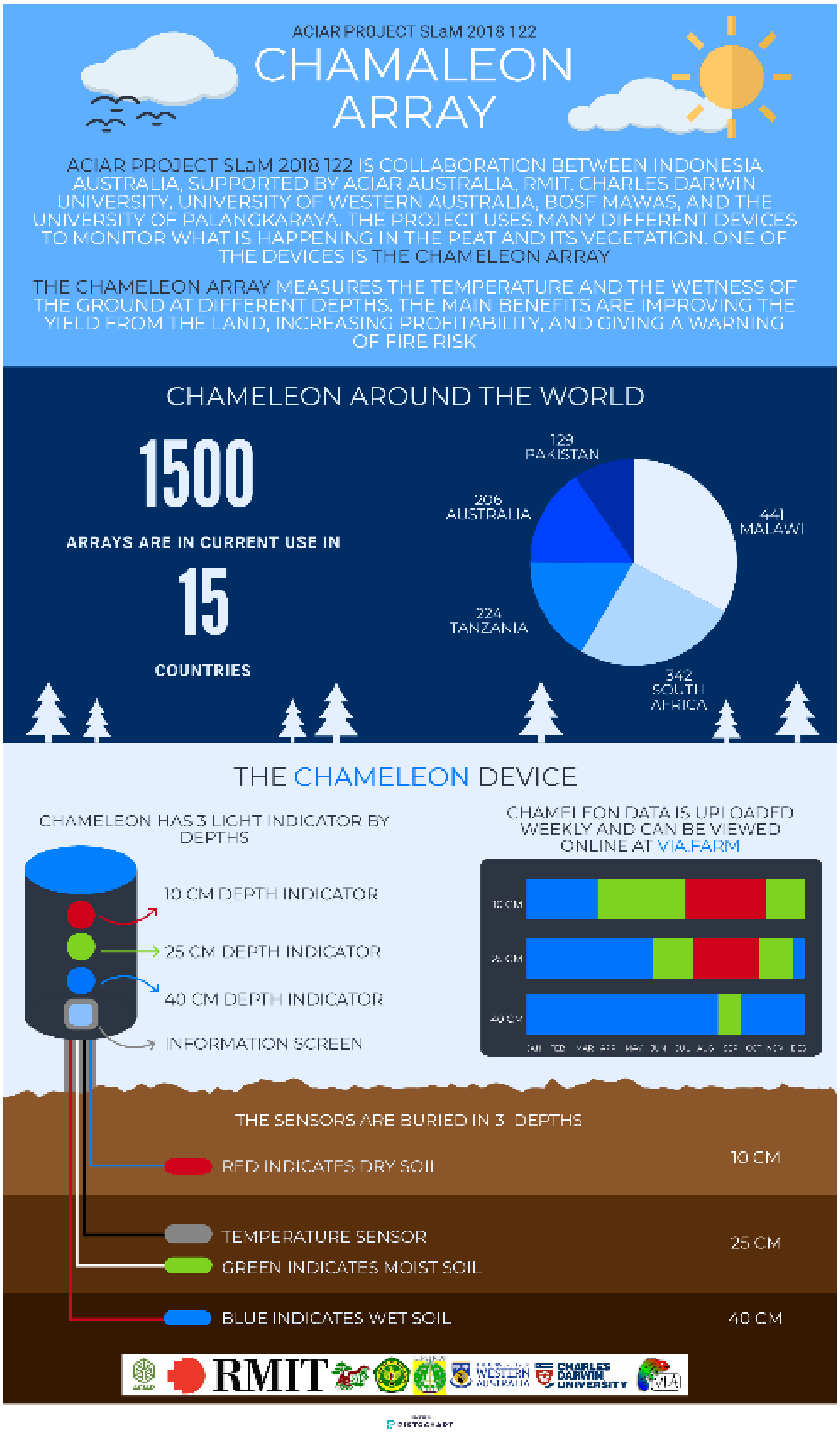
10.2 List of publications produced by project

Amanda L. Sinclair, Laura L.B. Graham, Erianto I. Putra, Bambang H. Saharjo, Grahame Applegate, Samantha P. Grover, Mark A. Cochrane (2020) Effects of distance from canal and degradation history on peat bulk density in a degraded tropical peatland, Science of the Total Environment, 699, 134199

11 Appendixes

11.1 Appendix 1:

Chameleons installed in Mantangai Village were accompanied by this Knowledge Product, conceptualised, designed and produced by BOSF junior researcher Nafila Izazaya



11.2 Appendix 2:

Chameleon Data is available to the public here

View the Chameleon data here:

https://via.farm/visualisefarm/351/

The codes that represent our Chameleons are as follows:

Chameleon code	Area	Irrigation Bay
LFT2C3	Tower	Flux
Security post	Security post	Flux
LFT1C1	Tower catchment	Flux
LFT1C2	Tower catchment	Flux
LFT1C3	Tower catchment	Flux
LFT2C1	Tower catchment	Flux
LFT2C2	Tower catchment	Flux
LFT2C3	Tower catchment	Flux
LFT3C1	Tower catchment	Flux
LFT3C2	Tower catchment	Flux
LFT3C3	Tower catchment	Flux
LR01	Reforestation	Flux
LMTU BOS	Village	Mantangai Village
LMTU TNI	Village	Mantangai Village
LMTU KDS	Village	Mantangai Village
BOSF PKY	Head office	BOSF Office Palangkaraya