Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: UOA 9		
Title of case study: Astro-Ecology: Tackling peat fires – a major contributor to climate change - using thermal imaging and drone technology		
Period when the underpinning research was undertaken: 2015-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Steve Longmore	Professor of Astrophysics	2013 - present
Serge Wich	Professor of Ecology	2012 - present
Period when the claimed impact occurred: 2015 - December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Using techniques from astronomy, we have developed drones with thermal cameras and an automated fire-detection system to tackle peat-fires. Working with Indonesian collaborators we have used the system over 2 Indonesian peat-fire seasons. Fire-fighters report the system is over 10x quicker finding fires, 50% quicker extinguishing fires and over 10x quicker confirming fires are extinguished. We estimate this has (i) saved 78 tons (156 trans-Atlantic flights) of CO_2 from entering the atmosphere per drone system per month; (ii) saved firefighters 200 days of hazardous smoke inhalation; (iii) reduced the toxic haze faced by the 15 million residents surrounding the fires.

2. Underpinning research

Our research aims to adapt the expertise that astronomers have in building and operating thermal infrared cameras to significantly reduce the extent and duration of peat fires. These fires comprise a significant fraction of annual anthropogenic CO_2 emissions – a main driver of climate change – and create a toxic haze which, in severe years, seriously affects the health of millions and has caused >100,000 premature deaths in Indonesia alone. Through a series of published research papers, we have demonstrated that techniques astrophysicists use to build, operate, and extract the maximum science from thermal infrared cameras on telescopes, are ideally suited to optimising the data collection and interpreting the data taken with thermal cameras on drones to detect peat fires. The project is effectively doing astrophysics, but rather than pointing into space, we are turning our "telescopes" back towards Earth to help tackle climate change.

Since 2015 we have been using astrophysics expertise to build drones equipped with commercial off-the-shelf (COTS) thermal cameras to help ecologists detect animals and humans using on drones. In 2017 we published our first paper demonstrating that astronomical source detection software is well suited to detecting warm objects (animals and humans in this case) in thermal drone images [UR1].

Building on this success, in 2017 we were awarded £50k from the UK Government's Science and Technology Facilities Council (STFC) [grant ST/P003273/1] to hire a postdoc to begin systematically adapting astrophysics techniques to work in real, field-site conditions. We subsequently published two papers at the start of 2018 describing how to adapt thermal-infrared technology and astronomical techniques to overcome environmental and atmospheric challenges to capture high precision thermal data for use in ecological studies [UR2,3].

Having successfully demonstrated the adaption of astrophysics techniques to work in real field conditions, later in 2018 we were awarded £412k of STFC funding (grant ST/R002673/1) to (i) begin using our thermal drone system to help conservation agencies around the globe and (ii) build a website with integrated machine learning analysis tools that can automatically find objects of interest in conservation images and videos. We have subsequently published multiple papers as a result of this work, demonstrating that thermal imaging from drones offers a major advance for ecological surveys [e.g. UR4,5].

When it became clear that the use of the system in the field was having an immediate and very positive impact on ecological surveys (see our other Impact Case Study), we began looking for other ways to capitalise on our research. In 2018 we began testing whether the system could be adapted to detect, identify, and help prevent the spread of peat fires, which are a major contributor to climate change. We conducted a very successful proof-of-concept experiment flying our system over controlled peat fires in Indonesia. In early 2019 we published a paper summarising the results of this research, showing that thermal drones are a safe and reliable method for detecting subterranean peat fires [UR6]. Building on the success of this research, we were subsequently awarded a £422k STFC GCRF grant (ST/S00288X/1) to train local stakeholders in the usage and maintenance of the system. This research and grant funding has led to the impact described below.

3. References to the research

All of these journal outputs were subject to a rigorous peer review process ahead of publication.

UR1. Longmore, SN, Collins, RP, Pfeifer, S, Fox, SE, Mulero-Pazmany, M, Bezombes, F, Goodwin, A, de Juan Ovelar, M, Knapen, JH and **Wich, SA** (2017) Adapting astronomical source detection software to help detect animals in thermal images obtained by unmanned aerial systems. International Journal of Remote Sensing, 38 (8-10). pp. 2623-2638. ISSN 0143-1161
Link: http://researchonline.ljmu.ac.uk/id/eprint/5173/

UR2. Burke, C, Rashman, M, McAree, O, Hambrecht, L, **Longmore, SN**, Piel, AK and **Wich, SA** (2018) Addressing environmental and atmospheric challenges for capturing high-precision thermal infrared data in the field of astro-ecology. In: Proceedings of SPIE. (SPIE. Astronomical Telescopes and Instrumentation, 10th-15th June 2018, Austin, Texas, USA).
Link: http://researchonline.ljmu.ac.uk/id/eprint/8925/

UR3. Burke, C, Rashman, M, **Wich, SA**, Symons, A, Theron, C and **Longmore, SN** (2019) Optimising observing strategies for monitoring animals using drone-mounted thermal infrared cameras. International Journal of Remote Sensing, 40 (2). pp. 439-467. ISSN 0143-1161
Link: http://researchonline.ljmu.ac.uk/id/eprint/9872/

UR4. Burke, C, Rashman, MF, **Longmore, SN**, McAree, O, Glover-Kapfer, P, Ancrenaz, M and **Wich, SA** (2019) Successful observation of orangutans in the wild with thermal-equipped drones. Journal of Unmanned Vehicle Systems. ISSN 2291-3467
Link: http://researchonline.ljmu.ac.uk/id/eprint/10675/

UR5. Spaan, D, Burke, C, McAree, O, Aureli, F, Rangel-Rivera, C, Hutschenreiter, A, **Longmore, SN**, McWhirter, PR and **Wich, SA** (2019) Thermal Infrared Imaging from Drones Offers a Major Advance for Spider Monkey Surveys. Drones, 3 (2). ISSN 2504-446X
Link: http://researchonline.ljmu.ac.uk/id/eprint/10539/

UR6. Burke, C, **Wich, SA**, Kusin, K, McAree, O, Harrison, M, Ripoll, B, Ermiasi, Y, Mulero-P·zm·ny, M and **Longmore, SN** (2019) Thermal-Drones as a Safe and Reliable Method for Detecting Subterranean Peat Fires. Drones, 3 (1). ISSN 2504-446X
Link: http://researchonline.ljmu.ac.uk/id/eprint/10221/

Total funding received for this research was **£975k** between 2014-2021, as follows:

1. STFC (Science and Technology Facilities Council) ST/P003273/1 “Astrophysics meets conservation biology” £50,405 (May - Jan 2018)
2. STFC ST/R002673/1, "Astro-ecology: the solution from the skies to save Earth's biodiversity" £411,988, Jan 2018-Dec 2019
3. STFC, Internal allocation of Global Challenges Research Fund "Preventing the spread of peat fires in Indonesia through novel use of above and below-surface fire detection with thermal imaging from drones ", £19,793 (2018)
4. STFC, ODA Institutional Award, £70k (2018-19)
5. STFC ST/S00288X/1 Developing automated detection and monitoring of peat fires in Indonesia with thermal infrared sensors under drones", £422,696 (£357,262), (April 2019- March 2021)

4. Details of the impact

Climate change presents the single biggest threat to sustainable development across the world[1]. Its widespread, unprecedented impacts – driven by increasing amounts of carbon-bearing greenhouse gases like CO_2 in the atmosphere – disproportionately burden the poorest and most vulnerable. The high carbon content of peat makes it one of Nature’s most efficient carbon stores. The annually re-occurring peat forest fires in Indonesia represent a substantial fraction (up to 15 – 20%) of the global anthropogenic CO_2 emissions[2]. In severe years they release more CO_2 than the entire global transport sector[3], thus greatly impacting climate change. The fires have additional devastating consequences. They lead to enormous economic losses[4] for tens of millions of Indonesian people, and the World Bank estimates that tens of millions of people suffer health problems from these annual fires[5].

Efforts are underway to find and contain the fires, but the challenges faced are considerable. For example, to completely extinguish a peat fire with an area of only 1m^2 requires 200 – 400 litres of water(!). Identifying the precise location of fires when they are small and more easily contained and extinguished is therefore vital. However, finding and then fighting fires on peatlands is difficult and dangerous work, owing to limited accessibility, water availability and visibility, particularly in remote and forested areas, plus the fact that peat fires can burn beneath the surface and re-emerge.

[1] https://unfccc.int/achieving-the-sustainable-development-goals-through-climate-action.
[2] Peat fire emission in South-east Asia in 2015 exceeded the 8.9Tg CO_2/day fossil fuel CO_2 release rate of the whole EU (Huijnen+, 2016, Scientific Reports, 26886). Average = ~1% of global fossil fuel emissions (Page+ 2016, Phil. Trans. R. Soc. B 371).
[3] Page et al., 2002, *Nature* **420**, 61–65.
[4] The World Bank estimates Indonesia lost USD 16.1 billion in 2015 alone (http://pubdocs.worldbank.org/en/643781465442350600/Indonesia-forest-fire-notes.pdf)
[5] For example, Crippa et al. (2016, Scientific Reports, 37074) estimate 69 million people were exposed to smoke for 3 months and 100,300 deaths arose from the 2015 fires alone.

Fire detection is traditionally carried out on foot, which is inherently very slow and person-intensive. Having reached the fire-zone, it can take large, experienced fire crews many hours of walking in near-zero visibility to pinpoint the fire location, especially when burning underground. This leads to prolonged exposure to extremely dense and harmful smoke inhalation, and horrific injuries by inadvertently standing and falling into fires burning underground. Drones have been tried as a potential solution to overcome these problems, but visible wavelength cameras cannot detect fires through smoke and vegetation, particularly for fires that burn underground.

Our research showed that our drone plus thermal infrared camera system can easily identify peat fires burning both underground and through the smoke – current fundamental bottlenecks in stopping the fires – from large distances. In September 2019 we delivered a thermal drone system to our Indonesian collaborators, and it has subsequently been used by fire-fighting teams in the Central Kalimantan province (the region often containing the most numerous, widespread and severe fires). For each fire, the fire-fighters recorded the GPS location, how long it took to extinguish, the number of person working days needed to tackle it, and the total area burnt. We asked our collaborators [the Borneo Nature Foundation (BNF), government agencies, universities and fire-fighting teams] for a joint letter quantifying the impact our system has had on finding and extinguishing fires.

In this letter, Bernat Capilla, Director of Programs at BNF, states*, "… the overwhelmingly positive feedback from fire-fighting teams and their desire for thermal drones to attend all possible fire events, attests to this positive impact. This derives from an increased ability and speed of detecting fires (compared to checking on foot, which is dangerous and may take many hours for a large fire, we estimate that use of a thermal drone allows fire hotspot location mapping to be completed around at least 10x quicker and with almost no safety risk), which in turn improves the ability of teams to monitor the current fire situation and deploy team members as necessary to prevent fire spread and extinguish hotspots. … The technology is also particularly useful in surveying fire sites post-initial fire-fighting, to confirm that all hotspots are extinguished and it is safe to leave the site, again increasing the speed of this by at least 10x. This is vitally important, as peat fires can smoulder beneath the surface, where they are difficult to detect without the aid of thermal imaging technology, and then re-emerge after fire-fighters have gone home, causing more damage."* Further quantitative impacts are summarised below.

Impact 1 – **Increased efficiency in finding/extinguishing fires**: The fire-fighters estimate that compared to traditional methods, our drone system accurately identifies the location of the fires over 10x quicker, helps extinguish them 50% quicker and makes it over 10x quicker to confirm fires are extinguished.

Impact 2 – **Substantial reduction in CO_2 released into the atmosphere**: Using the known amount of CO_2 that peat fires in the Kalimantan region emit per unit area (Setyawati & Suwarsono, 2018, IOPConf.Ser.: Earth.Environ.Sci. 166012041) and the spread rate of smouldering peat fires (Prat-Guitart et al., International Journal of Wildland Fire 2016, 25, 456–465), on average, the fires that were tackled released 1 ton of CO_2 (equivalent to 2 trans-Atlantic flights) per hour. Given the increased efficiencies described above, our drone system conservatively saves 3 tons of CO_2 from being emitted per fire. In October 2019, the fire-teams extinguished 26 fires using the drone. We are therefore saving roughly 78 tons of CO_2 (156 trans-Atlantic flights worth) from entering the atmosphere per drone system per month.

Impact 3 – **Improved health of firefighters and surrounding population**: the increased efficiency in finding/extinguishing the fires led to (i) virtually zero exposure to the previous safety risks finding fires; (ii) 200 days less smoke inhalation for the fire fighters, the effects of which are known to be extremely harmful; (iii) a corresponding drop in the concentration of toxic haze which had to be endured by the ~15 million Kalimantan province residents.

Impact of COVID-19: In 2020 we intended to bring additional drone systems with new automated fire-detection capability to additional fire teams in Indonesia. We believe this would have significantly increased the above impacts. However, COVID-19 travel restrictions meant it was not possible to deliver the systems.

5. Sources to corroborate the impact

Corroborating source 1 [**CS1**]: Joint letter of support from Indonesian collaborators written by Bernat Ripoli Capilla, Director of Programmes at the Borneo Nature Foundation.