PREPARING, RESPONDING OR RESTORING?

How technology is currently used in relation to climate change and rainforest protection in Indonesia

ALEXANDER VON HUMBOLDT INSTITUTE FOR INTERNET AND SOCIETY

PREPARING, RESPONDING OR RESTORING? HOW TECHNOLOGY IS CURRENTLY USED IN RELATION TO CLIMATE CHANGE AND RAINFOREST PROTECTION IN INDONESIA

STUDY
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SUSTAINABILITY, ENTREPRENEURSHIP AND GLOBAL DIGITAL TRANSFORMATION

EXECUTIVE SUMMARY

This working paper explores the climate change – technology – rainforest protection nexus. Specifically, it looks at how technology is (and can be) used to support three aspects of rainforest resilience: preparing for protection, responding to disturbances and restoring and revitalising rainforests. It was conducted on behalf of the Humboldt Institute for Internet and Society as part of its Sustainability, Entrepreneurship and Global Digital Transformation project.

The paper's objective is to stimulate further thinking and action on the role of technology in protecting Indonesia's rainforests by providing a high-level overview of the subject area. The paper brings together (academic) literature on climate change, technology and rainforest protection with insights from professionals from different fields and sectors working on rainforest protection in Indonesia. To achieve this, a rigorous six-step approach was followed, consisting of an initial structured literature review, stakeholder mapping, key informant interviews, acquiring feedback on initial findings, and a further literature review before incorporating further feedback into the final working paper. Literature and key informant interviewers were coded and analysed using MAXQDA to support a rigorous process.

Protecting rainforests is imperative given the key role they play in sequestering carbon and decelerating climate change, hence its inclusion as Sustainable Development Goal 15 which seeks to protect, restore and promote the sustainable use of terrestrial ecosystems, including forests. Moreover, rainforests provide key ecosystem services. Deforestation and degradation of rainforests is nonetheless an ongoing global problem. There have been attempts to halt this by incentivising rainforest protection through the Reducing Emissions from Deforestation and forest Degradation framework and Voluntary Carbon Markets. However, these have had mixed success and the costs and benefits of (not) protecting rainforests are unevenly distributed, making it complex to develop successful solutions.

Indonesia is home to the third largest rainforests in the world and tens of millions of Indonesians depend on rainforests for their livelihoods and utilise its wider ecosystem services. However, like elsewhere, Indonesian rainforests are constantly under threat from climate change, but also from the conversion of rainforests to land uses – particularly palm oil – that deliver more immediate and tangible benefits.

TECHNOLOGY, HOWEVER, DOES NOT OPERATE IN ISOLATION. IT IS ESSENTIAL TO UNDERSTAND HOW PEOPLE INTERACT WITH IT AND HOW THIS IS SHAPED BY INDONESIA'S SPECIFIC CONTEXT

Technology plays a key role in transitioning to a more sustainable future and is a broad term. It encompasses simple digitisation of pen and paper data collection tools as well as the use of satellite imagery and specialised soft- and hardware. Technology, however, does not operate in isolation. It is essential to understand how people interact with it and how this is shaped by Indonesia's specific context. To explore technology's role in rainforest protection, this study looks at three elements of resilience: 1) how to prepare for disruptions to rainforests, 2) how to respond to these disturbances, and 3) how to support the restoration or revitalisation of rainforests.

PREPARING FOR RAINFOREST PROTECTION

When it comes to preparing for disruptions, a lot of emphasis in the literature and interviews was on the monitoring of what happens in and around rainforests. Key technologies used for this are standardised digital data collection tools, acoustic monitoring and camera traps, remote sensing and drones, and geo-tracking. Using technology for preparedness is important because it is much more (cost-) effective to prevent disturbances than to respond to and recover from them. Satellite technology in particular has made monitoring rainforest cover much more effective and affordable. The emphasis of monitoring technology is on immediate disturbances to rainforests rather than long-term disturbances such as climate change. However, not all local-level actors involved in rainforest protection have the capacity to use all the technology that is available, so there are concerns around the accessibility of information. A gap remains between what is possible to support preparedness in theory and what technology is widely used in practice. Further compounding the difficulties in moving from information to action is that there are many actors involved in responding to disturbances, and it can be challenging to respond timely and effectively to identified disturbances.

A GAP REMAINS BETWEEN WHAT IS POSSIBLE TO SUPPORT PREPAREDNESS IN THEORY AND WHAT TECHNOLOGY IS WIDELY USED IN PRACTICE

RESPONDING TO DISTURBANCES

Key technologies used to respond to disturbances to rainforests are acoustic monitoring, drones and remote sensing and geo-tracking. These technologies enable more effective responses by informing responders in real-time about where the disturbance takes place. Acoustic monitoring and remote sensing technology can automatically alert designated contacts about events that need closer inspection. A challenge across all these technologies is that, especially in very remote areas, it can be difficult for people to act quickly on identified disturbances, so the effectiveness of technology is constrained due to the physical environment. Furthermore, not all (local level) stakeholders have the capacity to effectively utilise the available new technology and respond accordingly, and more time is needed for technology to ‘trickle down’ and become widely adopted. In parallel to reactive challenges, there are also proactive opportunities. Technology like geo-tracking offers an opportunity to verify the origin of products and thus a way to prove that they do not originate from protected forests. There is thus a situation whereby responding to disturbances is both reactive (responding to alerts) and proactive (creating incentives to help reduce the number of disturbances).

RESTORING AND REVITALISING RAINFORESTS

The use of technology for the restoration and revitalisation of rainforests appears to still be in its infancy, with remote sensing and drones being identified as the most promising technology. Remote sensing can help to identify the most effective places for restoring or replanting of rainforest. Not all (rain)forests are the same in terms of their ability to sequester carbon, so identifying the best areas for restoration can be important in a context with limited resources and competing priorities. Drones have been used to disperse seeds, contributing to forest (re)growth, though there are concerns about the scalability of this approach. Moreover, given the importance of providing sufficient economic incentives to the right stakeholders to protect rainforests, technology can also be helpful in bringing down the costs for restoration and revitalisation.

LOOKING FORWARD: USING TECHNOLOGY FOR RAINFOREST PROTECTION

It is recommended that further research is carried out into the climate change – technology – rainforest protection nexus by both academic- and practice-oriented stakeholders. It is essential to conduct more research on how climate change affects the health and resilience of rainforests, and what technology can do to protect this. Likewise, it is important to better understand how people living in and with rainforests can be more actively involved in rainforest protection, how the gap between availability and accessibility of data can be reduced, and what scope there is for technology to contribute more directly to the restoration and revitalisation of Indonesia's rainforests.

ACKNOWLEDGEMENTS

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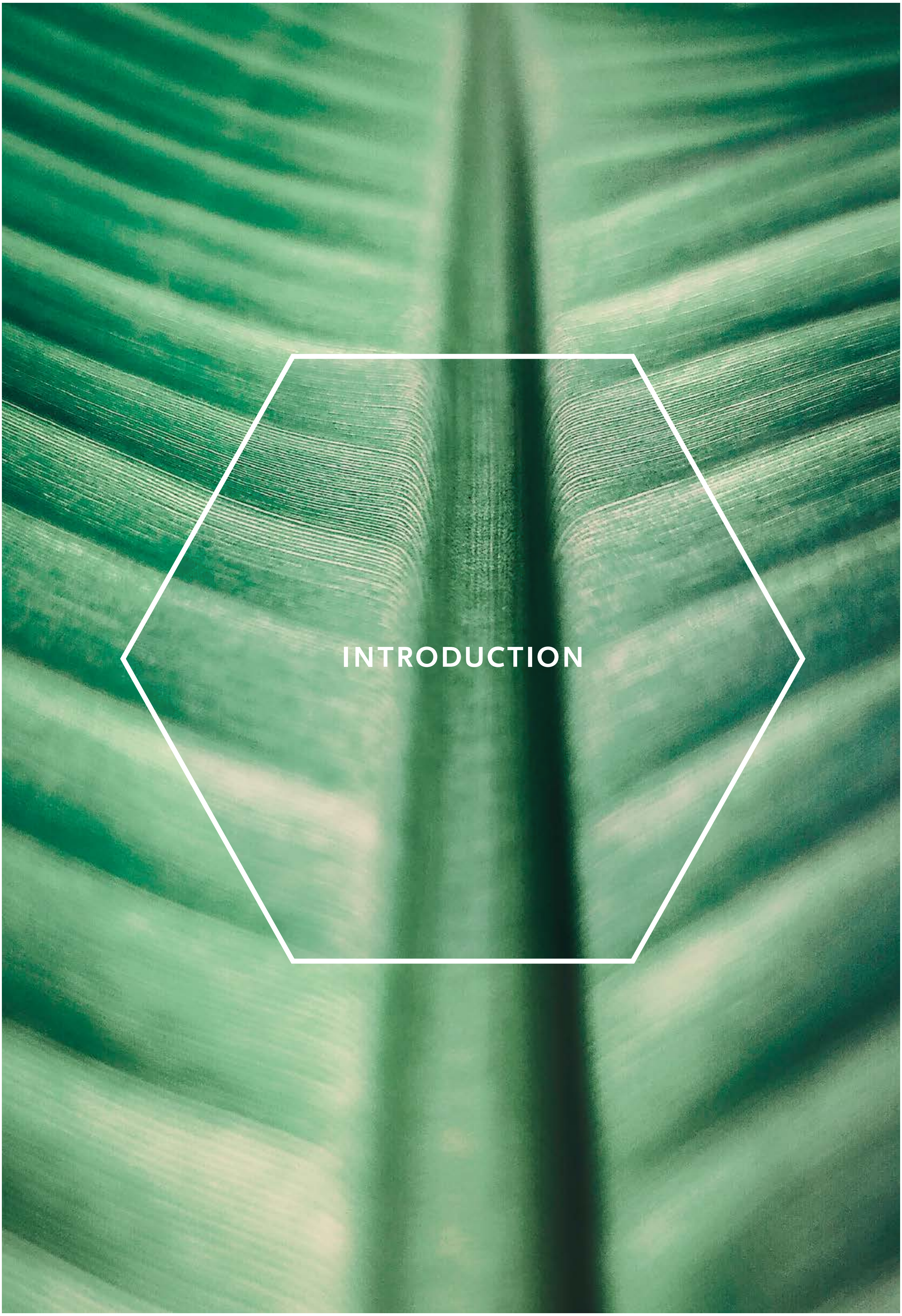
ABOUT THE PROJECT

Funded by the Gesellschaft für internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), the Sustainability, Entrepreneurship and Global Digital Transformation (SET) research project has the goal of addressing issues relating to digitalisation, particularly in the Global South. With a focus on the topics of entrepreneurship, platform regulation, and the use of digitalisation for climate resiliency, the project collaborates closely with local stakeholders to build application-oriented expertise and to create an international knowledge community.

CONTENTS

ACRONYMS AND ABBREVIATIONS

GIS	Geographic Information Systems
GPS	Global Positioning Systems
HIIG	Alexander von Humboldt Institut für Internet und Gesellschaft / Humboldt Institute for Internet and Society
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
MDG	Millennium Development Goal
REDD	Reducing Emissions from Deforestation and forest Degradation
SDG	Sustainable Development Goal



INTRODUCTION

This study explores how technology is (and can be) used in relation to climate change and rainforest protection in Indonesia. It was commissioned by the Humboldt Institute for Internet and Society (HIIG) as part of its Sustainability, Entrepreneurship and Global Digital Transformation project.1 The study recognises the importance of understanding how technology is put into practice and what obstacles and opportunities exist in developing and implementing (possible) digital solutions. It aims to bring together theory and practical experience, from global experts to people working on rainforest protection in Indonesia on a daily basis.

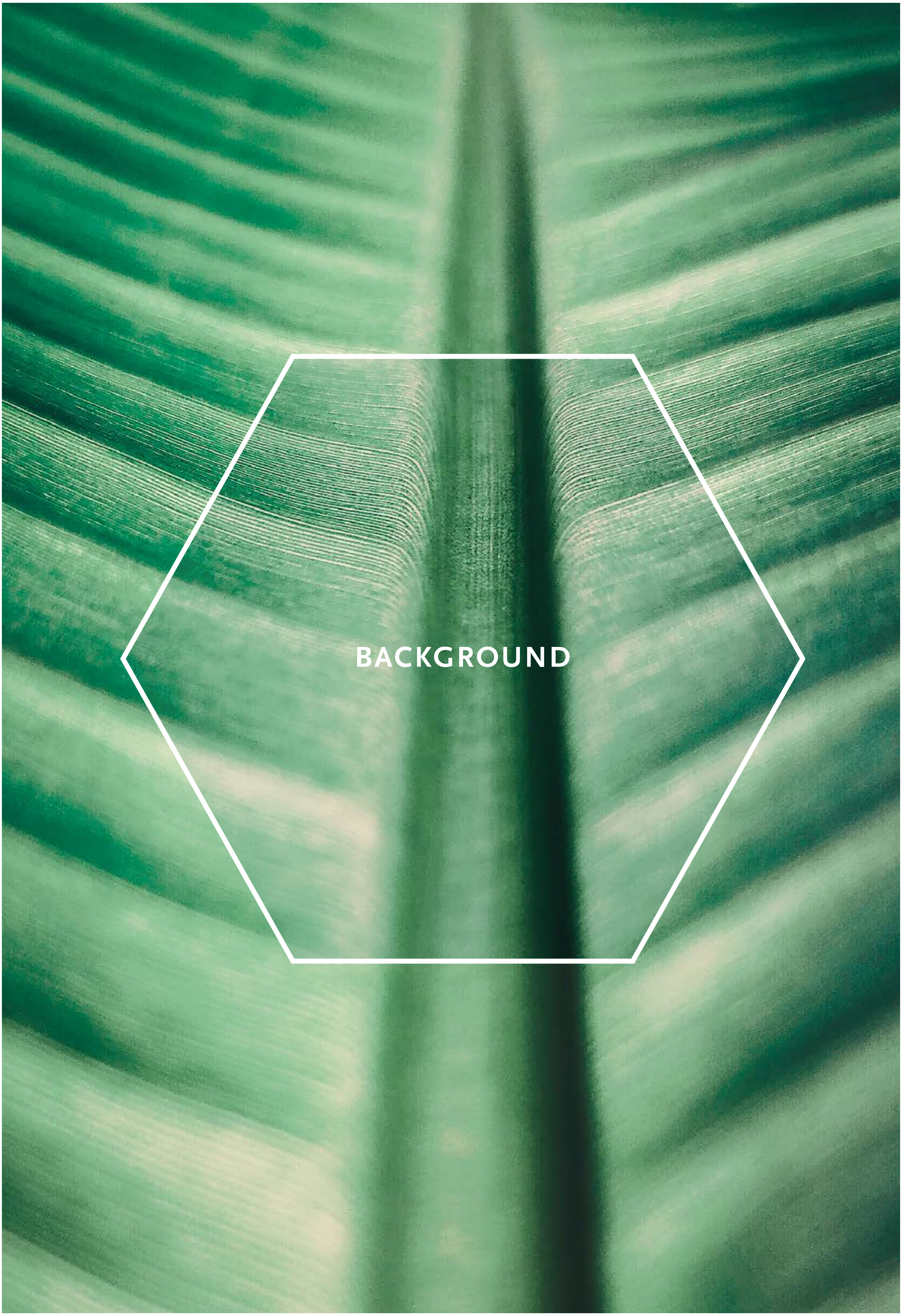
The aim of this study is to further stimulate thinking and action on the role of technology in protecting Indonesia's rainforests. It will do so by providing a high-level overview of the subject area rather than focusing on individual in-depth case studies. Unpacking how technology is (and can be) used to protect rainforests in Indonesia is a considerable undertaking and impossible to exhaustively address within the scope of this working paper. It is therefore important to recognise that while this paper attempts to provide a comprehensive insight into the subject, not all angles can be fully explored.

THE AIM OF THIS STUDY IS TO FURTHER STIMULATE THINKING AND ACTION ON THE ROLE OF TECHNOLOGY IN PROTECTING INDONESIA'S RAINFORESTS

The intended audience are people working – broadly speaking – in the field of rainforest protection, such as people employed by conservation organisations, policymakers, technical experts and researchers. This paper is therefore written in a way that is accessible to as great an audiences as possible, avoiding highly technical jargon around technology, conservation and resilience as much as possible – though references will allow the reader to explore further literature as per their interest.

The paper is structured as follows: first, Chapter 2 provides some background to the subject as well as background information specific to Indonesia and the major challenges it faces in protecting its rainforests. This is followed by Chapter 3 on the methodology and analytical approach. Chapter 4 provides an analytical framing of the different components of this study, particularly around technology and resilience. Chapter 5 then discusses this literature further and integrates it with information gathered through interviews. Chapter 6 discusses some of the implications of these findings, before Chapter 7 formulates conclusions and identifies areas for further research.

1 See https://www.hiig.de/en/call-for-proposals-digital-technology-climate-resilience-and-rainforest-protection-study/ for the original Call for Proposals.



BACKGROUND

GENERAL CONTEXT

The resilience of rainforests is continuously threatened by climate change and deforestation (Singh et al., 2022). Forests are important natural resources and account for one third of the earth's habitable land area (Ritchie & Roser, 2021). Aside from their significant ecological roles in mitigating climate change by sequestering carbon, forests provide food and medicine, and are a key source of livelihoods for people across the world (Bennet, 2017). Despite this important role, deforestation and degradation are an ongoing global concern – especially in tropical rainforests where most of this takes place. Globally, human-induced disturbances in tropical forests contribute 8–15% to global greenhouse gas (GHG) emissions, though some estimates put it even higher at 17% (Butarbutar et al., 2019, p. 1; Gené & Aliadi, 2010). Zeppetello et al. (2020) estimate that 3.5 million km2 of forest has been degraded or destroyed since 2020; this contributes to global warming, with the impacts most strongly felt in the areas of deforestation. The Intergovernmental Panel on Climate Change (IPCC) finds that "it is clear that across sectors and regions, the most vulnerable people and systems are disproportionately affected and climate extremes have led to irreversible impacts" (IPCC, 2022, p. vii). While the negative impacts of climate change are felt most strongly in low-income economies, the specific impacts depend very strongly on the resilience of the wider socio-ecological system (Whitfield et al., 2019). In other words: the impact of climate change is not the same everywhere or for everyone. The impact on rainforests, and the people depending on them at different scales, varies.

It is estimated that more than half of tropical forests are degraded as a result of human behaviour, causing a loss of biodiversity and release of carbon (Philipson et al., 2020). Deforestation and degradation contribute to climate change in two ways. First, reducing forest cover directly causes carbon emissions, accelerating climate change. Second, it reduces the size of forests to sequester carbon caused by emissions elsewhere. A primary cause of deforestation and degradation is the conversion of forest area for other forms of land use such as agriculture, palm oil production, mining, or simply for timber harvesting. There have been numerous initiatives at local, national and global levels to (financially) incentivise the conservation of rainforests, for example, through Voluntary Carbon Markets or the Reducing Emissions from Deforestation and forest Degradation (REDD and its successor REDD+) framework, which also seeks to support sustainable forest management (Enrici & Hubacek, 2018). These initiatives have had mixed success, including in Indonesia, as witnessed by the ongoing large-scale deforestation and degradation and the difficulties REDD(+) projects face in becoming economically sustainable (Butarbutar et al., 2019; Enrici & Hubacek, 2018).

LAND USE THAT LEADS TO DEFORESTATION AND DEGRADATION OFTEN RESULTS FROM ECONOMIC PRESSURES FACING INDIVIDUALS, COMMUNITIES, AND COUNTRIES

Land use that leads to deforestation and degradation often results from economic pressures faced by individuals, communities and countries (Obidzinski et al., 2012; Wijaya et al., 2019). Palm oil, for example, serves both as an export product and as a domestic substitute for fossil fuels, and in 2010 Indonesia produced 400 million litres (Obidzinski et al., 2012). In Indonesia, oil palm plantations area increased from 1.1 million ha in 1990 to 11.2 million ha in 2015 (Yuliani et al., 2020), demonstrating the incredible growth of the industry. The income from these activities generates significant benefits to countries and communities and should therefore be considered when thinking about rainforest conservation and how to strike a sustainable balance between conservation needs and alternative land uses. Deforestation cannot be seen separately from the livelihood challenges faced by communities living in forest areas.

PROTECTING RAINFORESTS IS CRUCIAL IN SLOWING DOWN CLIMATE CHANGE AS THEY ARE RESPONSIBLE FOR 55% OF ALL ABOVE-GROUND STORED CARBON. HOWEVER, MORE THAN HALF OF THE WORLD'S RAINFORESTS ARE DEGRADED AS A RESULT OF HUMAN ACTION

The protection of rainforests is crucial to slowing down climate change, as they are responsible for 55% of all above-ground stored carbon (Philipson et al., 2020). However, more than half of the world's rainforests are degraded as a result of human action, threatening biodiversity, reducing their ability to store carbon and directly leading to the emission of carbon currently stored within them (Handoko, 2014; Philipson et al., 2020). This is particularly acute in Southeast Asia, which has the highest deforestation rate in the tropics (Philipson et al., 2020, p. 838). It is also important to recognise that not every type of rainforest has the same capacity to store or release carbon (DellaSala et al., 2011, p. 30). Peat forests, of which 18% of the global stock is found in Indonesia, are particularly effective carbon stores for below-ground carbon (Novita et al., 2021) but are also under particular threat in Indonesia. The destruction of peat forests as a result of fires (either intentional or unintentional) and conversion to agricultural land or palm oil plantations causes significant releases of carbon into the atmosphere.

While there is a need to recognise the benefits alternative land use can bring at different levels, it is also important to recognise that forest ecosystems themselves deliver important benefits – often referred to as ecosystem services (Lakerveld et al., 2015; Singh et al., 2022). The benefits – and costs – of these ecosystem services are, however, unevenly distributed. Some individuals in a forest community might benefit from converting rainforest into agricultural land while others would benefit more from conserving the forest. Likewise, Indonesia has benefitted greatly in the short term from the conversion of forest into palm oil plantations. In the long run, however, the world at large might pay the price for the carbon released and the forests' reduced capacity to sequester additional carbon. The uneven distribution of benefits, costs and implications across time, space and place make rainforest protection incredibly complex and political, with different stakeholders continuously pursuing competing interests. Rainforest protection is thus situated in a continuous trade-off between the short- and long-term interests of different stakeholders (Campbell et al., 2010).

The importance of protecting rainforests has led to multiple initiatives over the past few decades, including most recently as part of the Millennium Development Goals (MDGs) and their successor, the Sustainable Development Goals (SDGs), adopted in 2015. MDG 7 centred around ensuring environmental sustainability, and included targets on reducing biodiversity and environmental losses. SDG 15 on Life on Land "aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (United Nations, n.d.). In 2014, the New York Declaration on Forests was launched – a partnership of governments, multinational companies, civil society, and indigenous peoples – with the aim of at least halving the rate of loss of natural forests globally by 2020 and striving to end natural forest loss by 2030 (Delabre et al., 2020, p. 1638).

With this understanding of the global context, and the recognition that impacts from climate change and deforestation are uneven, the next section focuses on Indonesia and its forests.

COUNTRY CONTEXT

Indonesia has the third largest rainforests in the world, after the Democratic Republic of the Congo and Brazil. Its rainforests "cover…87,614 million hectares that [is] almost equivalent to the sum size of three countries, Norway, Sweden, and Portugal. Indonesia's forests are home to thousands of plant and animal species, and 50-60 million Indonesians depend directly on the forests for their livelihoods" (Wijaya et al., 2019, p. 5980). Other estimates put the number of people who primarily depend on forests for their livelihoods at between 80 and 95 million people (Enrici & Hubacek, 2018, p. 8). This demonstrates the significance of rainforests and the need to protect them, not only to prevent the impact of deforestation and degradation but also to ensure the livelihoods of a significant portion of Indonesia's population of over 270 million.

However, deforestation and degradation continue to be significant problems in Indonesia. The rate of forest loss varies considerably from year to year, but takes place every year (Wijaya et al., 2019). "While tropical deforestation rates are tending to stabilize or to decrease in regions like Brazil, they are still increasing in Indonesia, driven by the international demand for wood-derived products as well as for agricultural land for oil palm and rubber plantations" (Guillaume et al., 2016, p. 49). The area covered by palm oil plantations has increased tenfold, from 1.1m ha in 1990 to 11.2m ha in 2015 (Yuliani et al., 2020). This increased area is not solely the result of deforestation, but it does point to the growth of the palm oil sector, which is of vital economic importance to Indonesia both as a source of biofuels for domestic use and for export (Obidzinski et al., 2012; Sandker et al., 2007). Ironically, the biofuels produced in Indonesia help to reduce its reliance on fossil fuels, which has a positive impact on reducing emissions from fossil fuels. The economic development needs of communities put rainforest conservation under further duress, and there is pressure to enhance the revenues gained from managing forests. "Moreover, since global warming that leads to climate change has [a] negative impact on the raising risks of hydrological-related disasters, including flood and drought, the government of Indonesia has stressed national involvement in climate change adaptation as well as mitigation" (Handoko, 2014). These competing pressures have led to intense debates between different stakeholders about land use and the conversion of rainforests as different interests collide (Sandker et al., 2007).

DEFORESTATION AND DEGRADATION CONTINUE TO BE SIGNIFICANT PROBLEMS IN INDONESIA

In Indonesia, local communities can gain the right to manage their local forests, and conservation organisations can help in developing forest management plans to support communities in maintaining forests in ways that support their livelihoods. Many of the projects need to produce accurate maps as part of monitoring forest cover, especially if they want to get REDD+ funding or sell carbon credits through Voluntary Carbon Markets. On a national scale, Indonesia has been producing such maps since 1990 using Landsat images, first every six years, later every three years, and annually since 2011, with increasing levels of detail such as the ability to identify burned surface areas (Wijaya et al., 2019). Conservation projects, however, typically need to produce their own maps separate from Indonesia's national ones.

In the global and Indonesia-specific context, a number of challenges can be identified in which there might be a role for technology:

1. More accurate information on rainforests is needed to improve the ability to make effective protection decisions. This information relates to:
    a.) The size/coverage of rainforests at different scales. Current estimates of coverage differ, complicating evidence-informed decision making. Conservation projects also need accurate coverage information to demonstrate their success.
    b.) The type of rainforests. Some (such as peat forests) might offer more climate benefits than others, so better information can help prioritise protection efforts.
    c.) The health/biodiversity/biomass of rainforests. This is key to accurately estimating the potential to sequester carbon, and thus informs decision-making.

2. More information is needed on how climate change (rather than deforestation and degradation) might affect rainforests (and consequently, the people depending on them).

3. Much deforestation and degradation is driven by economic incentives, so any technology that can improve people's livelihoods while conserving/protecting rainforests might help limit deforestation and degradation.

4. Technology is needed to directly stop deforestation and degradation and support the revitalisation of rainforests.

Chapters 5 and 6 explore more closely which types of technology can help address (some) of these challenges – though it is recognised that any single technology will only be able to contribute to solutions rather than act as a silver bullet by itself.

APPROACH AND METHODOLOGY

OVERALL APPROACH

The findings of this study must be grounded in the reality of rainforest protection. To achieve this, the study combines theoretical understanding and insights around technology and resilience with the experience of stakeholders involved in rainforest protection. This study went through distinct phases, elaborated below:

1. Initial literature review – the initial literature review started with a search for relevant literature, followed by an analysis of this literature using MAXQDA
2. Stakeholder mapping
3. Key informant interviews
4. 'Testing' of initial findings
5. Further literature review
6. Writing up of final findings

Phase 1: Initial literature review

The objective was to collect literature that reflects the global evidence and context as well as literature that addresses Indonesia's context specifically. The first 100 hits from Google Scholar were scanned to identify potentially interesting literature, with the long list based on publication titles. To establish the short list, all the abstracts from long-listed publications were read. Table 1 below lists the search terms and the number of long- and short-listed publications. Both academic and 'grey' literature was considered. Grey literature such as (non-academic) reports was included because the rainforest protection sector is dynamic and many of the stakeholders involved (international organisations, conservation organisations) do not always publish their insight/experiences academically, though they can be very relevant to this study. Publications that were shortlisted in a previous search query were not considered in subsequent queries.

Search	term	Long list	Short list
1.	'Resilience AND Rainforests'	22	7
2.	'Resilience AND Rainforests AND Technology'	22	14
3.	'Resilience AND Rainforests AND Indonesia'	23	14
4.	Resilience AND Rainforests AND Technology AND Indonesia'	17	5
5.	'Rainforests AND Indonesia'	20	5
Total		104	45

Table 1: Literature search results

Shortlisted literature was subsequently loaded into MAXQDA – a software programme which assists in the analysis of qualitative data. In MAXQDA, a coding structure was constructed based on our initial understanding of what key themes we were interested in. This deductive approach to coding was combined with inductive coding, whereby new codes were developed based on our developing understanding of the literature and subject matter. This coding framework then served as the basis against which the literature was analysed.

Phase 2: Stakeholder mapping

Stakeholder mapping was essential to gain a better understanding of the sector, and to identify potential organisations to approach for key informant interviews. To identify stakeholders, a two-pronged approach was taken. The first approach was to code all the (relevant) stakeholders mentioned in the literature reviewed as part of Phase 1. Relevance here was subjectively determined by the authors.[2] The second approach was to use the authors' own academic and professional networks to identify relevant stakeholders. The full stakeholder map is included as Annexe 1.

Phase 3: Key informant interviews

Key informant interviews (KIIs) were intended to 'ground' the insights from the initial literature review and to help understand both the opportunities and constraints to successfully using technology for rainforest protection in Indonesia. Potential informants were identified through stakeholder mapping and referrals (snowball sampling) from existing interviewees. In practice, it was extremely challenging to get people to agree to interviews, and the non-response rate to requests was high. Out of 25-30 approaches, only seven people agreed to be interviewed. A contributing factor to this, particularly when it came to interviewing local conservation organisations, was that the authors did not speak Indonesian.

Interviews lasted between 30-60 minutes, and notes from interviews were subsequently coded and analysed in MAXQDA. As informants did not give explicit consent to their names or organisations being mentioned publicly, their input was treated confidentially; where relevant, interview input is referred to by mentioning the type of organisation the respondent works for.

Table 2 provides an overview of the interviews, and references will be made to them by writing Interview # throughout this paper. No further identifiable details are provided, as respondents were interviewed in confidence.

Interview	Type of organisation
1	Conservation project in Indonesia, Sumatra
2	Organisation working on nature-based solutions to environmental problems, globally active
3	Private sector firm supporting sustainable agriculture, based in Indonesia
4	Research partnership focused on rainforests in South-East Asia, based in Malaysia
5	Technology firm focused on remote sensing and carbon, based in the Netherlands
6	Technology firm focused on remote sensing and carbon, based in Germany
7	Large conservation organisation in Indonesia, Kalimantan

Table 2: Interviewed stakeholders

2 For example, if literature covering the global context mentioned a local non-governmental organisation or government entity in sub-Saharan Africa or South America, this was not considered relevant for the purposes of this study.

Phase 4: 'Testing' of initial findings

Initial findings from the literature review and KIIs were presented at two events: during a public webinar organised by the HIIG and during a multi-stakeholder dialogue and event which took place in Jakarta, Indonesia.[3] During these events, a wide range of stakeholders from academia, practice and policy worlds provided feedback on emerging findings, helping to sharpen the analysis and direction of thought.

INITIAL FINDINGS FROM THE LITERATURE REVIEW AND KIIS WERE PRESENTED AT TWO MOMENTS: DURING A PUBLIC WEBINAR ORGANISED BY THE HIIG AND DURING A MULTI-STAKEHOLDER DIALOGUE AND EVENT WHICH TOOK PLACE IN JAKARTA, INDONESIA

Phase 5: Further literature review

Following the testing of initial ideas and suggestions for possible literature, these were reviewed. Any literature that was part of the initial search but had not yet been reviewed (due to time constraints) was now also reviewed and incorporated into the analysis.

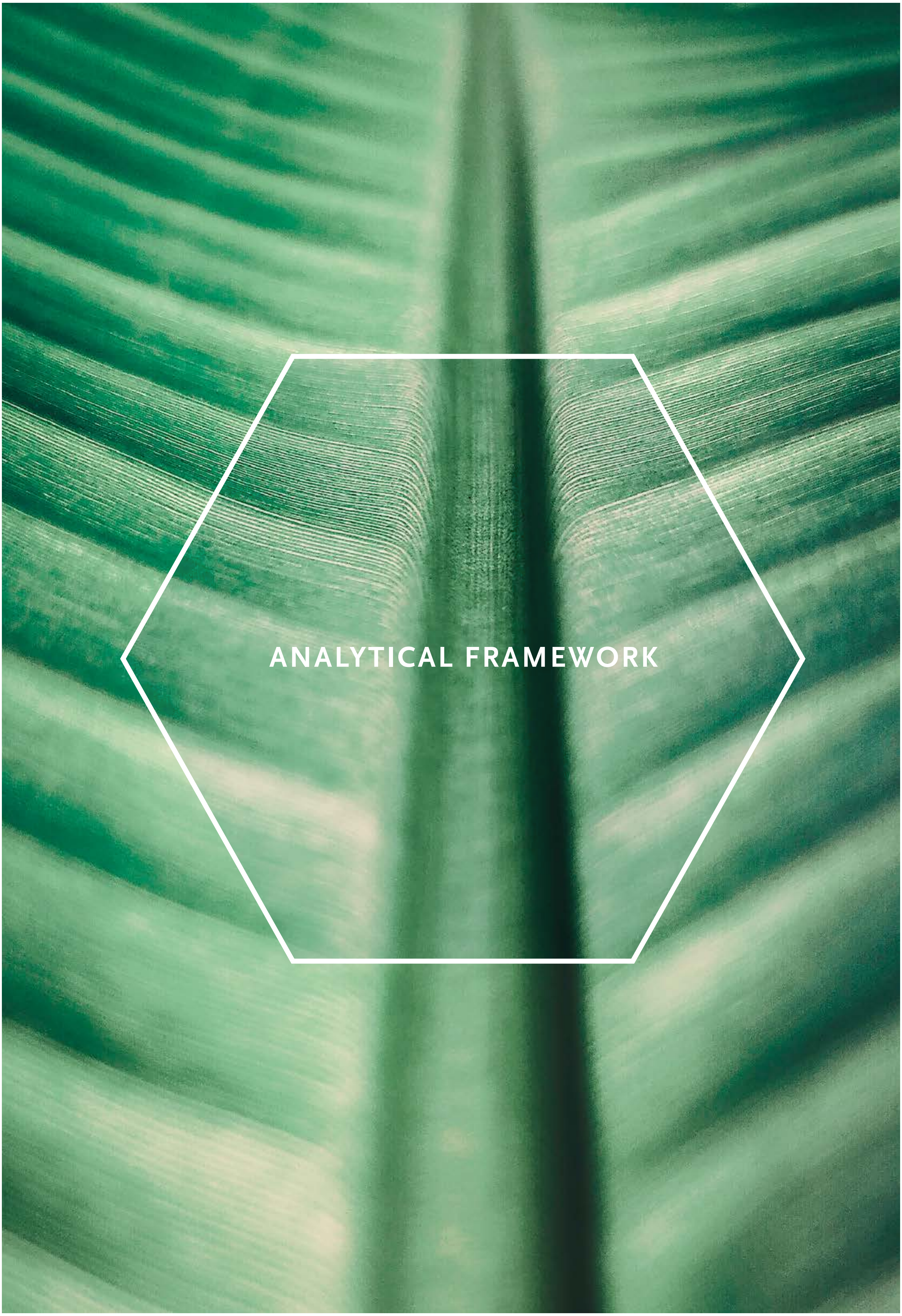
Phase 6: Writing up of final findings

The final phase consisted of drafting an initial working paper. This paper was subsequently provided to the project leader of the HIIG in February 2023 for a first round of comments. A second draft was provided to the HIIG mid-March 2023 for final comments. These comments were integrated to produce this final working paper, which was completed on 07 April 2023.

LIMITATIONS

Data collection and analysis faced some limitations. First, not all literature was Open Access, so not all publications could be accessed. Second, it was difficult to get people to agree to be interviewed, as many requests went unanswered and some people who in principle agreed at some point stopped replying. Third, the time and resources that could be invested in this study were limited, so some areas could not be fully explored – this study should therefore be considered as a 'conversation starter' rather than a definitive and exhaustive analysis of the subject matter.

3 The webinar took place on 17 November 2022. The multi-stakeholder dialogue and event took place on 13 December 2022.



ANALYTICAL FRAMEWORK

Technology and resilience are the central concepts in this study, and therefore warrant further elaboration on how they are understood in the context of this study, and how they can aid the understanding of rainforest protection and climate change in Indonesia. At the end of this section, a schematic overview is presented of the relationship between these different concepts and rainforest protection.

TECHNOLOGY IS CONSIDERED TO BE AN ESSENTIAL COMPONENT IN THE TRANSITION TO A MORE SUSTAINABLE FUTURE

Technology is considered to be an essential component in the transition to a more sustainable future, and something that can support sustainable development (Olsson et al., 2014; Stuermer et al., 2017). Technology encompasses a broad range of tools: from fairly straightforward tools that allow 'pen and paper' data collection to be digitised, to more advanced technology such as drones and the use of satellite imagery to monitor land use, and technology to trace whether products have been sourced (il)legally (Delabre et al., 2020). To utilise technology by and for people and their interests, it is important to understand the wider technological ecosystem (Stuermer et al., 2017). Stuermer et al. argue that a technological ecosystem "consists of all hardware devices, program files and data files that the user needs in order to process data". An information system could be "interpreted as socio-technical systems in which human actors and technical components are related and interact with one another", and a "digital ecosystem involves not only the technical components, but also the social elements" (Stuermer et al., 2017). As it is the interaction between humans and technology – the digital ecosystem – that eventually generates an impact on rainforests (for better or worse), this paper will dedicate significant attention to this wider digital ecosystem.

An essential component to making effective use of technology is the underlying data that is either fed into or produced by the digital ecosystem, and people's capacity to use this data. Data can be collected at different levels from local to global, and its outputs can be used to inform decision-making. However, insufficient (quality) data can be a severe obstacle to understanding progress/achievements in rainforest protection and to informing response strategies (Delabre et al., 2020; Whitfield et al., 2019). A lack of (good quality) data, for example around carbon stocks, also poses obstacles to the development of effective policies (Novita et al., 2021). Data itself, however, is not a silver bullet. In Indonesia technology has been increasingly developed in support of forestry planning, but the capacity to utilise this technology has not kept pace. There is therefore a need to build capacity among stakeholders, including with government (at different levels) and non-governmental organisations (Wollenberg et al., 2009). Research from Borneo further shows that for technology to be successfully and sustainably introduced into forest communities, it is essential to bring people along in the deployment of this technology and avoid heavy top-down approaches that 'force' technology onto communities (Bala et al., 2020).

A key area in which technology is being used, in addition to coverage mapping, is in measuring biomass. Increasingly sophisticated tools are available to (remotely) measure biomass and the health of forests. This is important for more accurate estimations of how much carbon forests can store and how successful efforts to restore and revitalise degraded forests are. Ecosystems with high levels of existing resilience recover from disturbances more quickly than low-resilience ecosystems (Hendrix, 2018).

Resilience in the context of this study is understood as "the capacity of any entity – an individual, a community, an organisation, or a natural system – to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience" (Chang et al., 2020; Rodin, 2014). It is worth highlighting that systems are not 'fixed'; they change constantly as the wider environment changes (Whitfield et al., 2019). As well as changes from climate change, there are also more immediate shocks to rainforests as a result of human behaviour, for example due to deforestation.

The key aspect to resilience is that these systems are able to maintain and deliver their core ecosystem services despite disturbances. Shocks and stresses come in the form of 'fast onset' disturbances such as forest fires, droughts and floods and 'slow onset' disturbances such as climate change. Whitfield et al. (2019) describe short-term weather events (such as extreme rainfall or drought) that are less than 1 year in duration, while long-term processes (such as climate change) take place over a period of multiple decades. Short- and long-term disturbances can of course be related, with changes to the climate causing short-term disturbances, so these processes must be understood as (sometimes) entangled rather than completely separated.

Enduring stress from disturbances – climatic and otherwise – and bouncing back is thus key. This does not mean socio-ecological systems like rainforests cannot adapt or change – on the contrary, adaptation is key to resilience (Dewi, 2013) – but the important thing is for the system, Indonesia's rainforests in this case, to be able to continue to carry out their critical functions, such as acting as a carbon sink (Butarbutar et al., 2019). Indonesia recognises the importance of increasing the resilience of its forests, and has developed strategies to enhance this that focus on reducing exploitative land use, but successful implementation of these strategies has been challenging (Goh & Lee, 2021).

In summary, several relevant analytical elements around rainforest protection emerge, displayed in a simplified form in Figure 1. Rainforests, being central to this study, are placed at the heart of the graphic. Their resilience is based on three components: 1) the ability to prepare (them) for disruptions, 2) their ability to respond to disruptions, and 3) their ability to adapt or recover from disruptions. The resilience of rainforests is affected by both long- and short-term disturbances – the latter particularly driven by short-term economic pressures. Reducing the size and resilience of rainforests in turn has negative implications for the storage of carbon, which causes the immediate release of carbon currently stored and reduces opportunities for forest-related livelihoods. These negative effects lead to new long- and short-term disturbances, causing the cycle to repeat. Technology can intervene across this entire cycle in helping to prepare for disturbances by monitoring what is happening on the ground, it can help prevent further degradation and deforestation by supporting stakeholders to respond to disturbances, and it can help to promote the revitalisation of rainforests. The next chapter discusses how technology is (and can be) used to protect rainforests in Indonesia, based on the reviewed literature, KIIs and the feedback received during project events.

TECHNOLOGY CAN INTERVENE ACROSS THIS ENTIRE CYCLE IN HELPING TO PREPARE FOR DISTURBANCES BY MONITORING WHAT IS HAPPENING ON THE GROUND, IT CAN HELP PREVENT FURTHER DEGRADATION AND DEFORESTATION BY SUPPORTING STAKEHOLDERS TO RESPOND TO DISTURBANCES, AND IT CAN HELP TO PROMOTE THE REVITALISATION OF RAINFORESTS

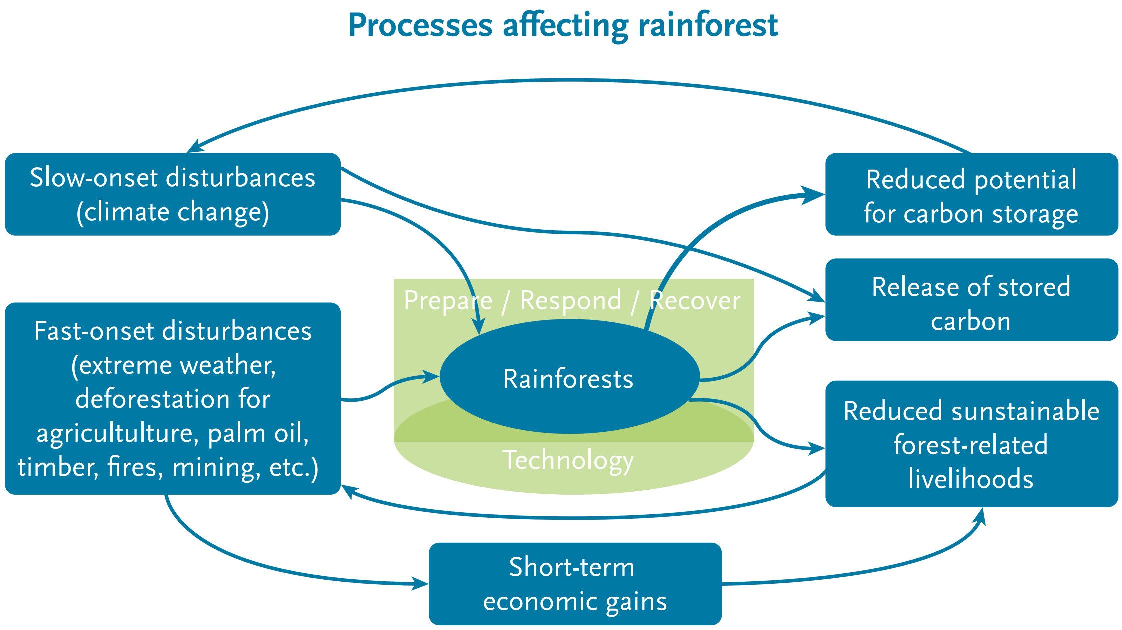
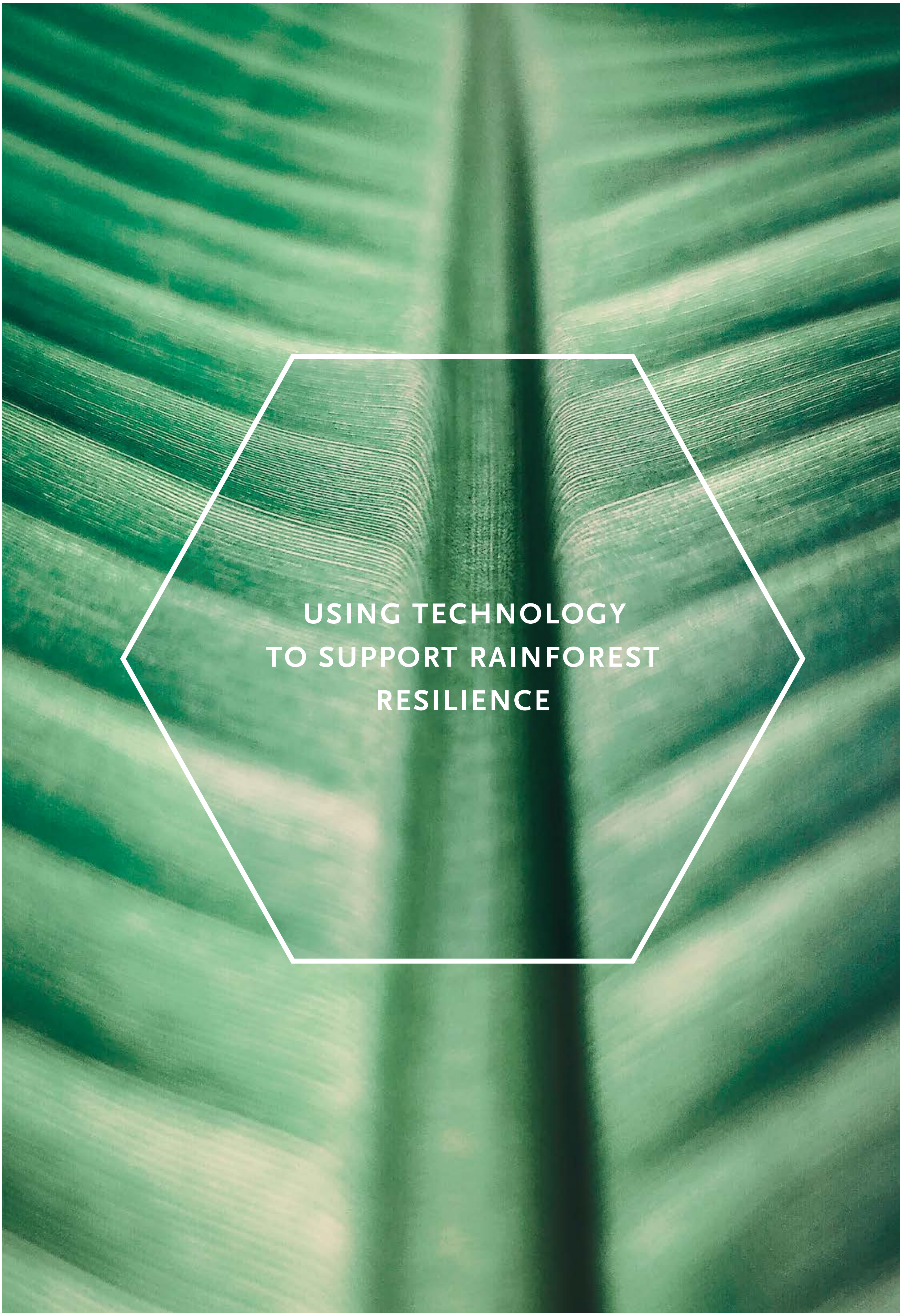


Figure 1: Processes affecting rainforests



USING TECHNOLOGY TO SUPPORT RAINFOREST RESILIENCE

This chapter looks at how technology is (and can be) used to protect Indonesia's rainforests. It is structured along the three dimensions of resilience. The first section looks at the role technology has in monitoring disturbances. Section 2 focuses on how technology can help to respond to disturbances. Section 3 then discusses technology's (potential) role in helping rainforests to adapt and restore after disturbances have taken place.

TECHNOLOGY FOR PREPAREDNESS

Key technologies: Standardised digital data collection tools, acoustic monitoring and camera traps, remote sensing and drones, geo-tracking.

Taking action prior to disasters occurring is more cost-effective than responding to them after the disaster has happened (Keating et al., 2017). This makes it even more relevant to explore how technology can aid in understanding and detecting risks to rainforests as well as supporting solutions. Technology comes in different shapes and forms, from relatively basic to highly advanced. The entire range is being deployed to support rainforest protection in Indonesia. On one end of the spectrum, there are basic smartphone applications that can help people to more easily enter and store monitoring data on biodiversity, while on the other end there are initiatives that automatically alert conservation projects when changes to forest cover are identified through automated analysis of satellite images.

SMART Conservations Tools[4] offers a platform which people can use to log observations and conduct biodiversity monitoring (Interview #2) on handheld devices such as smartphones, which are increasingly common even in remote locations. While some say the tool could use some improvement, the benefit of involving community members directly in conservation efforts is huge, especially when the data quality is good and standardised for analysis. A problem raised in interviews was that many organisations now sit on large amounts of data which are often in paper form and/or of varying quality, making their analysis more difficult – and that is if the responsible organisations even have the human capacity to process and utilise this data. Using technology to improve the quality of data – and perhaps automate some of the analysis – therefore offers great potential to better monitor what is happening on the ground (Interview #4).

Local-level monitoring on the ground also takes place using acoustic monitoring and camera traps. Acoustic monitoring essentially allows organisations to install monitoring devices such as Forest Guardian[5] in a forest, which can send people alerts when, for example, the sound of a chainsaw is detected within 1km (Interview #1). The software in the device automatically monitors the surroundings and analyses sound in real time. This in turn creates the potential for a response, and as such it is a technology that enables both monitoring and direct action to protect rainforests. Camera traps, meanwhile, can play an important role in monitoring the biodiversity of a rainforest,

4 https://smartconservationtools.org/

5 See https://www.hackster.io/phatta/forest-guardian-267cb7#overview

for example by monitoring which animals inhabit a particular area and which are difficult to identify from above using drones, due to canopy cover. Animals, and particularly large mammals, play an important role in maintaining rainforest resilience (Lindsell et al., 2015).

Technology that contributes to improved data collection and quality at ground-level can directly contribute to addressing challenges and improving information about forest health, biodiversity and biomass. This requires both hardware (e.g. acoustic monitoring hardware, cameras, smartphones or other data entry devices) and software (applications to collect and analyse data) solutions to be developed in ways which are accessible to people involved in rainforest protection, including for people living in rainforests who might have had limited formal education and who speak a range of languages.

On the other end of the spectrum, remote sensing and the rise of Global Positioning Systems (GPS) and Geographic Information Systems (GIS) have greatly improved the ability to monitor rainforest coverage, the health of rainforests and the way they evolve. As such, these technologies are one of the most fundamental means of preparing for the protection of rainforests at scale. GPS and GIS data can subsequently be analysed, for example to identify areas at risk or monitor illegal practices.

While previously accurate satellite imagery was perhaps prohibitively expensive, and some technology still is, more affordable and even free Earth Observation data sources have become available, such as NASA's Landsat data and the European Space Agency's Sentinel data (Interview #3). The availability of free data is essential, as many forest conservation projects are driven by results-based finance, and any cost makes it more difficult for them to develop a viable business case. Communities that want to start a conservation project and sell carbon credits through the Voluntary Carbon Market or access REDD+ funding need to be able to produce good baseline data on forest cover and biodiversity and subsequently monitor this (Interview #2). Reducing the cost of access to such technology is thus an important step.

When very high-resolution satellite data is not needed, the costs of imagery is not the problem, but the human resources to effectively use these data might be a challenge, especially for smaller conservation projects who might lack the resources to employ experts that can use the technology effectively (Interview #1, 2, and 3). It is not uncommon for people who work at local conservation projects and have good technical skills to move to larger organisations in Jakarta or abroad. People with technological skills move to places where they can earn a better income and develop their skills further, leading to a concentration of technical skills in urban areas and among a few organisations and firms.

Much of the satellite monitoring that takes place focuses on monitoring changes to forest cover, biomass and land use, such as whether illegal logging has taken place since the previous round of data collection. Near real-time monitoring of forest coverage also takes place through theForest 2020 initiative[6], used to identify which areas are most at risk of deforestation (Interview #2) so that

6 See https://ecometrica.com/forests-2020/

appropriate action can be taken before it is too late. Global Forest Watch[7] also makes it possible to get weekly alerts when deforestation takes place. As such, it is very responsive and focused on the short-term disturbances highlighted in Figure 1.

Drones offer a solution 'in between' very localised 'on the ground' monitoring and satellites. They can – and are – used to support forest mapping and documentation (Interview #7). They are particularly useful in terrain which is difficult to access, when an overview of a larger area above the canopy is needed, or when it is crucial to get real-time information.

Remote sensing technology – particularly the software needed to process and analyse imagery and provide meaningful outputs – can directly address the identified challenges around information on land use and rainforest coverage, type and health. It thereby plays a crucial role in supporting evidence-informed decision-making. Using drones for monitoring also requires a combination of hardware (the drones), software and human resources to be effective.

Climate change itself as a long-term disturbance can, of course, also affect rainforests, for example through changing rainfall partners and sustained temperature changes. The south-eastern Amazon is expected to become drier due to climate change, which could eventually result in forests becoming savanna ecosystems (Hendrix, 2018; Staal et al., 2015, p. 65). In this regard, technology also offers potential in Indonesia. The interviewed conservation project indicated that they are noticing changes in precipitation, and that water sources that used to flow all year are now sometimes dry (Interview #1). If water sources dry up, and conseque Forest Watch ntly plants get less water, 'ground observations' from conservationists can be corroborated using remote sensing technologies which can measure water content in biomass.[8] This will help to identify whether anecdotal observations also hold up over time and across larger areas. Currently, however, the conservation project does not have the capacity to carry out such analysis themselves. It is thus important that when talking about the availability of data, the accessibility of data is also considered, because simply making more data available does not guarantee that it can be effectively accessed and utilised by conservation projects. This highlights the need to not only consider the technological ecosystem but to think about the wider digital ecosystem, which includes social aspects (Stuermer et al., 2017).

Remote sensing technology can therefore also help improve the quality of information (and thus decision-making) on the impact of climate change on rainforests. However, it seems to be less developed/used compared to the previously described technological solutions around information on land use. This is especially the case at micro/local level, as the current focus of remote sensing technology is around identifying land use. Part of the problem is that conservation projects are more concerned with, and able to affect/respond to, short-term disturbances. Long-term disturbances like climate change often originate outside the boundaries of a particular conservation effort, and with limited resources it is understandable that conservation actors focus on what they can meaningfully influence. Technology that can help protect rainforests from long-term disturbances might

7 See https://www.globalforestwatch.org/

8 See, for example, the work done by Stanford University's 'Remote Sensing Ecohydrology Group': https://koningslab.stanford.edu/research/remote-sensing-vegetation-water-content-and-soil-moisture

therefore be of more current interest to governments and other actors, including in academia, that focus on larger scales of rainforest protection.

Another technological innovation in monitoring is geo-tracking (Interview #3). There is growing global demand for products that are sourced and produced with sustainability in mind. In December 2022, the European Parliament took a big step by requiring companies to verify that the products they sell within the EU have not contributed to deforestation or degradation.[9] This created a requirement for companies to be able to monitor their supply chains, which technology can – and already does – play an important role in. For example, by using remote sensing and tracing technology, timber companies can prove that the location of the timber they sell comes from a patch of forest designated for harvesting. By comparing these tags with remotely sensed information about surrounding forests and production, it should become much more difficult to insert unsustainably sourced timber into supply chains reaching the EU.

Overall, technology is already being used and has further potential for preparing for rainforest protection. While technology can help monitor land use in (protected) forest areas and the impact of climate change, monitoring by itself is not enough. Another important aspect is the capacity and will to enforce regulations, which remains a critical challenge in Indonesia (Dewi, 2013). The next section looks at how technology is used to respond to disturbances identified through monitoring.

TECHNOLOGY FOR RESPONSE

Key technologies: Acoustic monitoring, drones, and remote sensing and geo-tracking.

Technology plays a key role in supporting stakeholders to respond more effectively to disturbances, whether they are conservation actors, government entities or the private sector. Four key response technologies were discussed during interviews.

First is the usage by conservation projects of acoustic monitoring. Alerts sent by acoustic monitoring devices enable stakeholders to rapidly respond, either directly themselves or by contacting the relevant authorities or other actors. In practice, tools like this are helpful, but no panacea. First, people still need to be able to receive the alert, which can be difficult in rural areas where phone coverage limited. It is also not feasible to deploy such hardware across very large areas. At least as important, however, is the capacity to take enforcement action once an alert is received. Typically, enforcement of rainforest protection is the responsibility of local government authorities such as the police or forest management units, and by the time these have been contacted and arrived at the scene (which can be difficult in parts of the rainforest), the damage might have been done already.

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9 https://www.europarl.europa.eu/news/en/press-room/20221205IPR60607/deal-on-new-law-to-ensure-products-causing-deforestation-are-not-sold-in-the-eu

The second response technology is drones. These have been actively used to respond to forest fires in Indonesia – again in support of stakeholders such as firefighters active on the ground (Interview #7).[10] Drones equipped with thermal imaging hardware and software can be used to detect fire hotspots and relay this information to firefighters so they can more effectively deploy their resources. This is, however, quite a complex undertaking which requires specialists to operate the drones, make sense of the data and effectively interact with firefighters, so it is not a solution for small-scale or resource-constrained stakeholders (Interview #7). Moreover, while any improved ability to respond to forest fires is welcome, the logistics mean it cannot necessarily be deployed at scale (Interview #4). The logistics of getting a firefighting response underway in remote forest areas is very challenging. On a national level, the Government of Indonesia also continuously uses satellite imagery to monitor fires (Wijaya et al., 2019; Interview #6), though the response challenges remain the same.

A combination of remote sensing and geo-tracking also offers an opportunity to respond to threats to rainforests. Together these technologies enable companies and consumers to verifiably purchase goods that have been sourced sustainably. It is thus a technology that, while not directly preventing deforestation or degradation, creates incentives to protect rainforests by supporting people with livelihoods that can sustain themselves and the rainforests surrounding them.

Overall, however, it seems that technology is used less to respond to disturbances than it is to monitor. Again, it becomes evident that technology continuously intersects with humans and that the digital ecosystem around rainforest protection should also consider the capacities to respond to identified disturbances. The technology discussed in this section therefore primarily addresses challenges around information and the ability to act on it, and challenges to livelihoods.

TECHNOLOGY FOR RESTORATION

Key technologies: Remote sensing, drones.

RESTORING AND REVITALISING RAINFORESTS IS KEY TO ACCELERATING ABOVE-GROUND CARBON STORAGE

Restoring and revitalising rainforests is key to accelerating above-ground carbon storage – though there are questions around what the most effective and efficient ways to do so are, and the costs involved (Philipson et al., 2020). With forest cover diminishing in South-East Asia, it becomes essential to understand how regrowth and revitalisation can take place and how resilient the ecosystem is. A key concern when (re)growing forests is how much time it takes to compensate for the carbon losses resulting from deforestation (Butarbutar et al., 2019), let alone to increase carbon storage beyond pre-deforestation and degradation levels.

10 See https://www.borneonaturefoundation.org/saving-the-rainforest/

Not every type of forest is the same when it comes to storing or releasing carbon. Peat swamp forests are particularly effective carbon stores as they store carbon above and below ground (Novita et al., 2021). When these are converted to palm oil plantations or 'replaced' with other types of forests which only store carbon above-ground, the net effect on carbon emissions is still negative, even if the total amount of forest remains the same or even increases. However, more studies are needed to identify which types of forest protection are most effective and where the best places for intervention lie, so that prioritisation can take place (Interview #2). Remote sensing technologies which help understand biomass and the health of forests and soils can be useful in this regard by identifying the areas where restoration activities might be most valuable. The challenge is to effectively use scientific information obtained through remote sensing in actual policy and practice.

A second technology that can aid restoration is drones, which can partially take over the role played by mammals when it comes to dispersing seeds (Lindsell et al., 2015). Drones have been used in Kenya as part of reseeding efforts[11] to distribute seeds and a major conservation organisation in Indonesia indicated they are exploring similar approaches (Interview #7). There are, however, practical challenges: the required drones are expensive and difficult to operate. Moreover, another key informant indicated scepticism about using drones for large-scale seed dispersal due to the short germination time of seeds and the logistics involved, especially in remote areas (Interview #4).

Another important aspect to consider when it comes to forest restoration is that the financial incentives need to be sufficiently high. Some suggested that it will be important to think more carefully about how conservation projects can meet people's livelihood needs in a sustainable way, and that currently this is done insufficiently (Interview #3). Research suggests that although prices in the voluntary carbon market vary and fluctuate greatly, they are often below "the minimum value required to offset the cost of restoration by tree planting and maintenance" and REDD+ projects face similar problems on the incentive side (Enrici & Hubacek, 2018; Philipson et al., 2020). From a technology perspective, this suggests that unless prices for offsetting carbon increase significantly, technology could play an important role in bringing down costs for restoration and revitalisation, making it easier to develop viable conservation business plans.

11 See https://blog.flyinglabs.org/2021/07/07/drones-are-helping-large-scale-reforestation-efforts-in-kenya/

TECHNOLOGICAL OPPORTUNITIES AND LIMITATIONS

Chapter 2 identified a number of key challenges for rainforest protection in Indonesia, and Table 2 revisits these based on the above discussion.

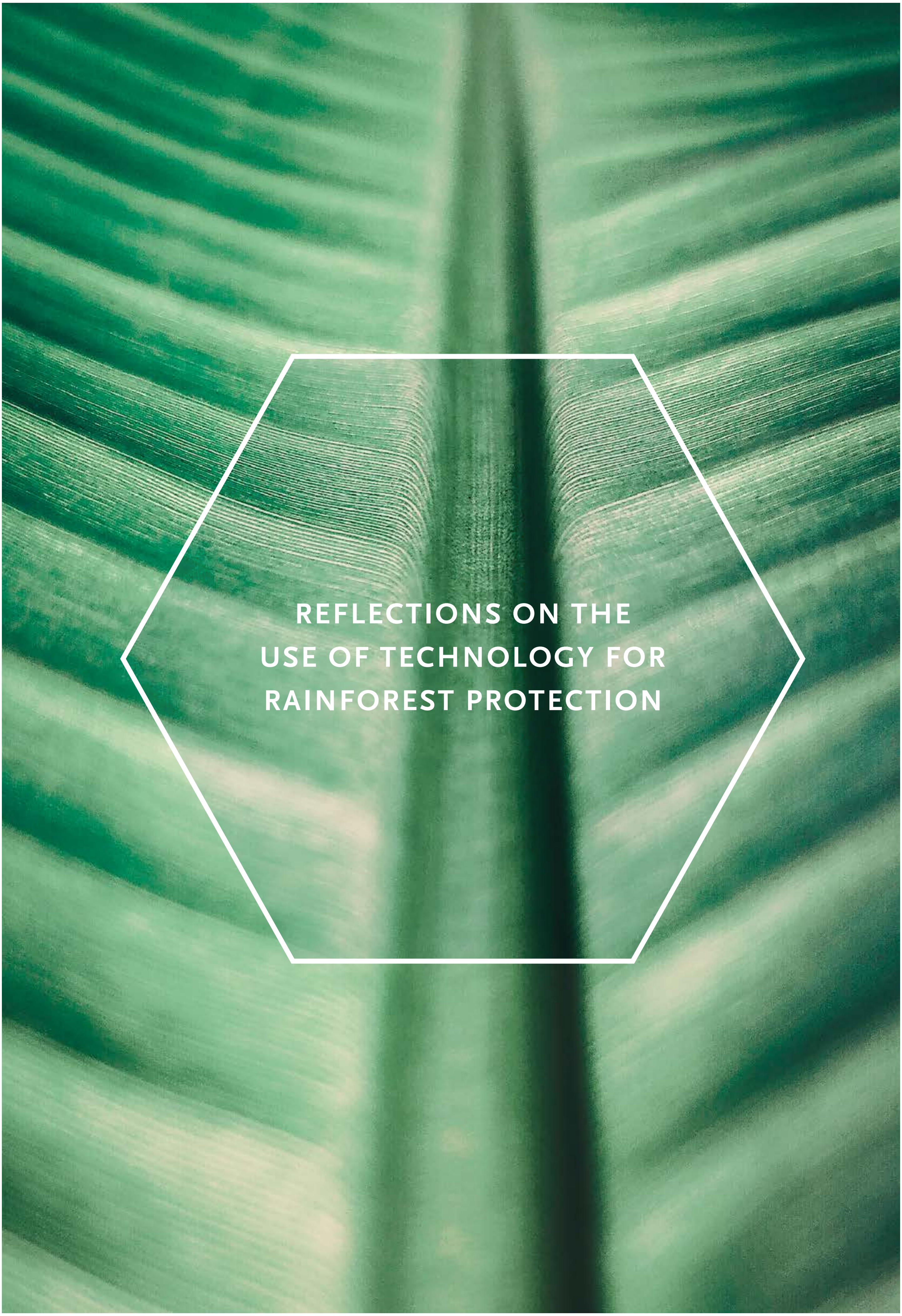
Challenge	Technology	Opportunity	Challenge
1.a: More accurate information on rainforest coverage	Remote sensing	Improved satellite/remote sensing technologies improve accessibility of coverage data.	Human capacity to effectively use this data.
1.b: Improved information on forest types	Remote sensing	Improved satellite/remote sensing technologies enable better identification of which forests to protect and restore.	Technology not yet widely used/accessible. Effective policy and practice responses based on this data.
1.c: Improved information on health/biomass/biodiversity	Remote sensing, data collection tools	These technologies help to gain more insight into forests, if protection/restoration actions are effective, and can involve local communities.	Effective policy and practice responses based on this data. Developing tools that are accessible and usable given the skills and capacities of people using them and recognising infrastructure limitations in remote areas.
2. Improved information on climate change's impact on rainforests	Remote sensing	Remote sensing can create insights into long-term change and disturbances at different scales.	Effective policy and practical responses based on this data. Creating incentives for conservation actors to focus on the long term rather than immediate threats and disturbances.
3. Strengthening livelihoods	Remote sensing and geo-tracking	Improving opportunities to verify the sustainable origins of products, which could protect livelihoods. Helping to verify conservation projects' efforts and providing access to voluntary carbon markets.	Deploying these technologies at scale and making them affordable. Capacity of (smaller) conservation actors to effectively use these technologies and develop successful business/livelihood plans. The regulatory environment regarding voluntary carbon markets might change, as could the value of carbon credits.
4. Technology to stop deforestation and degradation	Remote sensing, acoustic monitoring, drones	Better information gained through these technologies can enable conservation actors and authorities to identify threats quickly and respond to them effectively.	Technology is not always accessible, even if it is available. A combination of actors is needed to respond to identified threats and disturbances. The cost and required human capacity to acquire and effectively operate technology can be an obstacle. Response logistics, especially in remote areas, can hinder action.

Table 3: Opportunities and challenges of using technology for rainforest protection.

Overall, two main observations can be drawn on the practical aspects of using technology for rainforest protection. First, technology is primarily used to improve stakeholders' knowledge of the short-term threats and disturbances faced by Indonesia's rainforests. Good data is increasingly available due to the use of technology, particularly through remote sensing, though other technologies also increase the availability of data. Second, a major challenge exists around the effective use of such information. Human capacity, especially among smaller conservation actors, is sometimes limited – which limits the use of technology. Moreover, information by itself does not protect rainforests from deforestation or degradation – human action is required. Responding to threats and disturbances and revitalising rainforests is dependent on actors having the right incentives, and while there are ways in which technology can support this, it is an area in which technology still plays a relatively small role.

TECHNOLOGY IS PRIMARILY USED TO IMPROVE STAKEHOLDERS' KNOWLEDGE OF THE SHORT-TERM THREATS AND DISTURBANCES FACED BY INDONESIA'S RAINFORESTS

A MAJOR CHALLENGE EXISTS AROUND THE EFFECTIVE USE OF MONITORING DATA. HUMAN CAPACITY, ESPECIALLY AMONG SMALLER CONSERVATION ACTORS IS SOMETIMES LIMITED WHICH LIMITS THE USE OF TECHNOLOGY



REFLECTIONS ON THE USE OF TECHNOLOGY FOR RAINFOREST PROTECTION

Based on the preceding analysis and wider reflection on the interviews and literature, the following overarching insights can be drawn around the (future) use of technology in rainforest protection.

REFLECTING ON PREPARATIONS

THE FIRST STEP TO EFFECTIVELY PROTECTING RAINFORESTS IS TO ENSURE THAT THE RIGHT PEOPLE HAVE THE RIGHT INFORMATION FOR DECISION-MAKING AND ACTION

The first step to effectively protecting rainforests is to ensure that the right people have the right information for decision-making and action. Equally, in a digital ecosystem it is essential to understand the interaction between technology and humans (Stuermer et al., 2017). A big gap remains between what is possible from an academic/theoretical and technological point of view and what technology and information is (widely) used in practice and by whom (Interviews #1, 2, 3, 4, 5). When it comes to rainforest protection in Indonesia, this is also evidently the case. There are increasing opportunities on the technological side, particularly to improve monitoring and the availability of information about the state of rainforests and the short- and long-term threats and disturbances they face. At the same time, the capacity to effectively utilise this information is constrained by a lack of human capacity, especially among smaller conservation actors, such as local projects and institutions which aim to protect rainforests.

The impact of climate change on rainforests also receives less attention than the fast-onset disturbances shown in Figure 1. The literature on rainforest protection, climate change and technology is focused on land use and the negative consequences this can have on rainforests. There is also a lot of attention to how deforestation and degradation contribute to climate change. Likewise, the key informants interviewed focused mostly on fast-onset threats and disturbances and the potential and actual technological solutions to them. However, long-term processes set in motion by climate change also negatively affect rainforest resilience (Hendrix, 2018; Staal et al., 2015). Preparations for rainforest protection thus focus primarily on one type of threat. One challenge in preparing for long-term challenges, according to Whitfield et al. (2019), is that no-one is really accountable for addressing them. As a result, there is a need for much more research on how climate change can affect rainforest resilience and what role technology can play in addressing long-term threats. Without clear understanding of who is responsible and accountable for addressing such long-term threats, it is likely that preparing for them will remain on the back burner, even though the implications of a lack of preparedness will be felt globally.

REFLECTING ON RESPONSES

WELL-TRAINED PEOPLE ARE A PRECONDITION FOR SUCCESSFULLY USING TECHNOLOGY TO RESPOND TO THREATS TO RAINFORESTS

Well-trained people are a precondition for successfully responding to threats to rainforests and using technology to do so. However, skilled people working at grassroots conservation projects in Indonesia tend to move to larger organisations in pursuit of better employment opportunities, leaving smaller actors without key human resources. While the cost of some technology, such as access to satellite imagery, is going down and is often even available for free, the costs for analysing this data beyond relatively straightforward coverage monitoring is high and increasingly seen as a 'specialism'. As a result, there appears to be an increasing specialisation in the climate change – technology – rainforest protection nexus. Firms conducting more advanced analysis are only incentivised to develop new technology if they can capture the benefits of their innovation (Stuermer et al., 2017).

A private-sector ecosystem is therefore developing which attracts the most skilled people who offer their services for a fee (Interviews #3, 5, 6). New solutions are developed to help respond to threats, partially driven by the emergence of cloud computing and the advantages offered by being able to serve multiple clients and achieve economies of scale, reducing the costs for soft- and hardware which would be unaffordable for smaller organisations. A dual process thus takes place whereby technology offers new opportunities for rainforest protection, but the knowledge of these technologies does not (yet) land with local-level organisations. It remains to be seen if/when the required skills and technology trickle down – just as the use using satellite imagery was first inaccessible to small actors but is now freely available to anyone and widely used for basic monitoring. From a response perspective, this creates an important challenge because there is an increasing number of 'nodes' in the system. This can be both beneficial and detrimental. Specialists working full-time using the latest technology can monitor more effectively. Technology could then help to quickly relay this information to actors on the ground who can respond to the threats more effectively than in a situation whereby local organisations need to monitor the rainforest they protect with outdated technology alongside their other responsibilities. However, as more layers or nodes are introduced into the response process, there is also increased scope for mistakes or miscommunication. Moreover, these services are not free, so organisations with fewer resources will be deprived of the information they need to effectively respond, especially to fast-onset threats.

Another key element in protecting rainforests in Indonesia is ensuring that people have an economic incentive to maintain rainforests rather than converting them for other land use purposes. Economic pressures on people are a major threat to rainforests (Obidzinski et al., 2012; Wijaya et al., 2019), so finding ways in which protecting rainforests can be aligned with people's livelihood needs is essential. Conservation projects attempt to do so, but they often find it challenging to design plans that will provide livelihoods in sustainable ways (Interviews #2, 3). This is further complicated by the uneven distribution of benefits, with some stakeholders benefitting from deforestation while others benefit from maintaining rainforests (Campbell et al., 2010). The communities who are 'made responsible' for protecting rainforests and achieving global or national commitments often have limited means to do so and depend on stakeholders and market forces outside their control (Delabre et al., 2020).

Geo-tracking technology is an example of how technology can help to protect rainforests in a proactive way. There is a growing market of consumers who want 'green' and 'sustainable' products and private sector companies meet this need by developing technology. If communities can successfully insert themselves into this global supply chain, there might be economic opportunities that they can tap into which support the protection of rainforests. However, it leaves their livelihoods vulnerable to changes in global demand – just as projects based on income from voluntary carbon markets are strongly dependent on the global marketplace and policies around them. Based on the analysis here, it seems that technology can offer opportunities for improved livelihoods for some people/communities. However, a big remaining challenge is that there might continue to be incentives at local/national/global levels which offer more immediate and larger incentives, for example to convert rainforests into palm oil plantations or to increase mining operations. It is much less clear how – and if – technology offers opportunities for sustainable livelihoods given the wider environment in which forest livelihoods are embedded.

Protecting rainforests thus requires both proactive and reactive steps to be taken, and technology has potential in both areas. Using drones to support firefighters can be seen as reactive while supporting sustainable land use through geo-tracking timber (products) can be seen as proactive.

REFLECTING ON REVITALISATION

Revitalisation is probably the least explored aspect in the climate change – technology – rainforest protection nexus. A big question remains around how Indonesia's ambition of having millions of hectares of rainforests managed by communities can be achieved, and what role technology will play in this. The possibilities explored here – using remote sensing to identify key areas for reforestation and protection and using drones for seed dispersal – are still in their infancy. Interviews did not point to any 'breakthrough' technologies with regards to revitalisation, and the accessibility and scalability of existing technology was frequently challenged.

At the same time, increasing the health of rainforests and making them more resilient to both short- and long-term threats is key to maintaining the vital role rainforests play in acting as a carbon sink and slowing down climate change. It is therefore important that increased effort is invested in exploring what role technology can play in this regard by both academic and non-academic stakeholders.

INCREASING THE HEALTH OF RAINFORESTS AND MAKING THEM MORE RESILIENT TO BOTH SHORT- AND LONG-TERM THREATS IS KEY TO MAINTAINING THE VITAL ROLE RAINFORESTS PLAY IN ACTING AS A CARBON SINK AND SLOWING DOWN CLIMATE CHANGE

RECOMMENDATIONS FOR FUTURE RESEARCH

Through the research conducted for this working paper, several areas for further research have been identified. These are separated into recommendations for more academic-oriented research and practice-oriented research – though ideally stakeholders from both areas will collaborate.

ACADEMIC-ORIENTED RESEARCH QUESTIONS

1. There is a need for more research on how climate change itself affects rainforests. When considering Figure 1, a lot of research takes place on how short-term disturbances affect rainforests, just as there is considerable research on how deforestation and degradation contribute to climate change. However, the dynamic of how climate change as a long-term disturbance affects rainforests is currently under-researched. Given the (potential) impact of long-term changes in the climate on rainforests, it is essential this is addressed in order to understand the full interaction between rainforests and climate change.

2. can technology be used to support the overall resilience of rainforests? The current focus of research is on how technology can help people to prepare for fast-onset threats and disturbances to rainforests, while paying scant attention to the role of technology in helping stakeholders to respond to these threats or to revitalise rainforests after a disturbance. Strong academic research into this could support non-academic stakeholders develop solutions which can have an impact at scale.

3. How specialisation affects rainforest protection. As identified, advanced technology – and especially the skills needed to operate it effectively – are concentrated in specialised firms. Equally, the preparation of carbon reports for conservation projects is often outsourced by these projects to specialists elsewhere who have the required technical expertise. There thus seems to be an ongoing process of specialisation in the rainforests protection sector. But as far as we are aware, there is no clear insight into how such processes affect rainforest protection and its implications on the roles of different stakeholders, particularly that of (smaller) conservation projects for whom the costs of external expertise might be prohibitive.

PRACTICE-ORIENTED RESEARCH QUESTIONS

1. How can people living in and with rainforests be more involved in rainforest protection? A lot of the focus of this paper has been on technological possibilities, and the challenges of having sufficient capacity at a local level to utilise these effectively. However, it seems little attention is given in the literature to how local knowledge of rainforest protection is integrated into (potential) technological solutions, even though the responsibility for protecting rainforests is often devolved to the local level. Involving the people who live in and with rainforests and who know the local context in the development of technology might lead to interesting solutions that are practical and accessible. Therefore, it might be pertinent to explore the following two questions:
   a.) How can indigenous knowledge about rainforest protection be integrated into technology used for rainforest protection?
   b.) How can technology actively involve people living in/near rainforests, recognising the skills, capacities and constraints of people and their physical environment? Steps are already being taken to make smartphone applications/data collection tools available in different languages and to make them work in areas with limited connectivity. A fuller exploration of what technology would be beneficial from a grassroots perspective, is well-worth conducting.

2. How can technology help to make information more accessible to those working directly on rainforest protection? Monitoring technology generates a lot of information, especially around short-term disturbances. However, this information is not always accessible to those at the local level who work on rainforest protection. There is thus still a step to be made to package/present information in such a way that information is 'ready to use' by people without specialised knowledge.

3. How can technology enable stakeholders to better respond to both slow- and fast-onset threats and disturbances? Related to the previous question, there is a step to be made in moving beyond information gathering/provision to active responses. Technologies like Forest Guardian and drones greatly facilitate responding to immediate threats such as illegal logging and forest fires. However, there are still a lot of intermediate steps that need to take place, and especially in very remote areas, their utility is constrained.

4. How can technology support the revitalisation of rainforests? Perhaps the most under-researched area relates to the revitalisation of rainforests. Aside from efforts to support seed dispersal and identifying priority areas for reforestation, there seems to be limited activity in this area, despite its significant importance given the ongoing deforestation and degradation.

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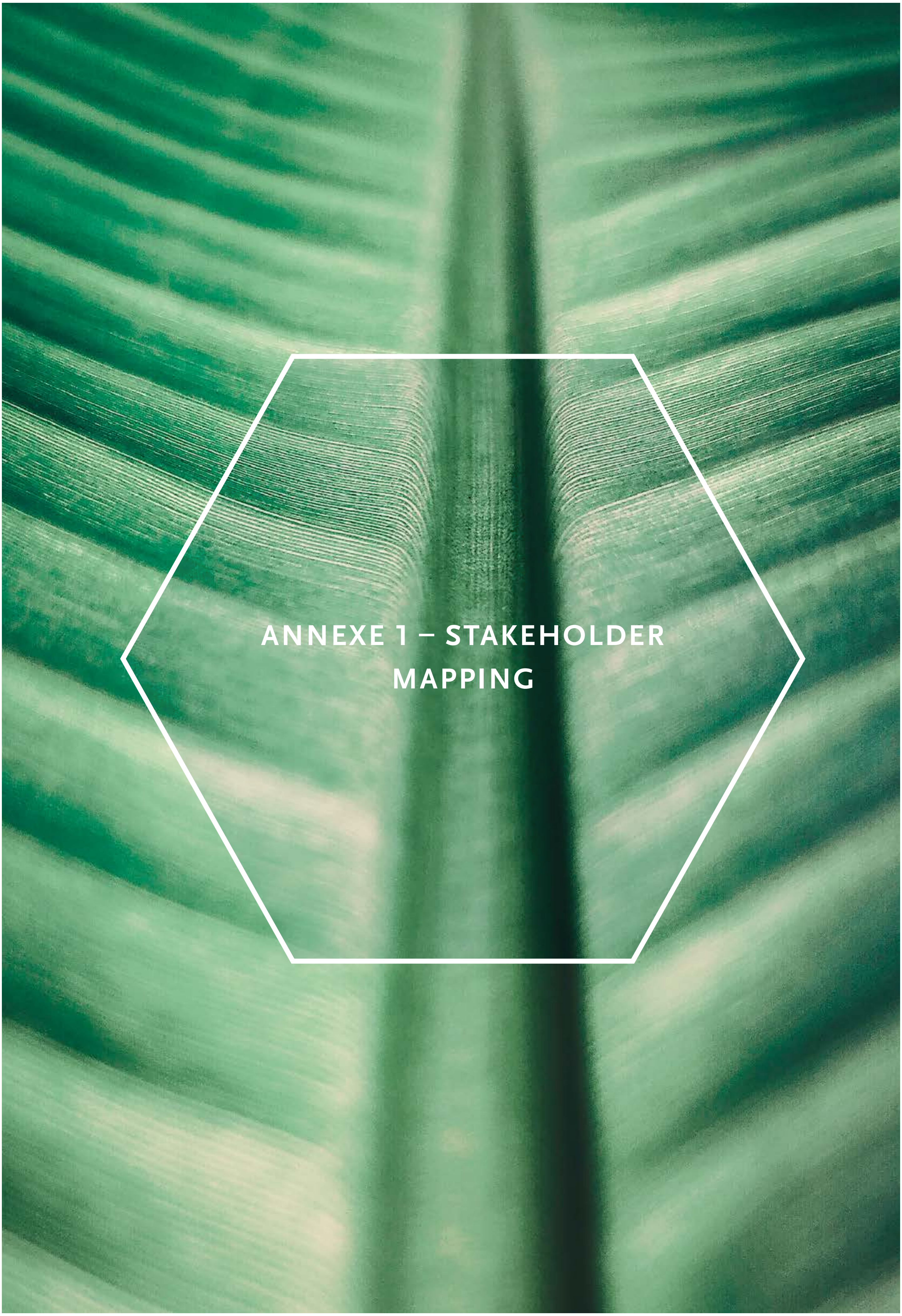
ANNEXE 1 – STAKEHOLDER MAPPING



Sn	Name	Government	Conservation Organisation	Private Sector	Research / Knowledge Institute	Others
1	World Resource Institute Indonesia				✘	
2	Ministry of Environment and Forestry	✘				
3	Indonesian Space Agency (LAPAN)	✘				
4	GIZ- Forest and Climate Change Program					✘
5	Centre for International Forestry and Research				✘	
6	SMART Research Institute				✘	
7	Burung Indonesia/ Bird-Life International		✘			
8	Royal Society for the Protection of Birds		✘			
9	PT Restorasi Ekosistem Indonesia		✘			
10	Norwegian Embassy Jakarta					✘
11	KfW Bankengruppe					✘
12	World Bank's Carbon Fund					✘
13	Danish International Development Agency (DANIDA)					✘
14	German International Climate Initiative (ICI)					✘
15	Singapore Airlines			✘		
16	Voluntary Carbon Stan-dard/Verra		✘			
17	National Land Use Agency					
18	Ministry of Agriculture	✘				
19	District Forestry Office of Boven Digoel	✘				
20	District Agriculture Office of Boven Digoel	✘				
21	Mongabay					✘
22	Akar Bhumi		✘			
23	BBKSDA (central govern-ment)		✘			
24	PERHUTANI		✘			
25	German Science Founda-tion (DFG)					✘
26	Stability of Rainforest Mar-gins (STORMA)				✘	

Sn	Name	Government	Conservation Organisation	Private Sector	Research / Knowledge Institute	Others
27	UBRA, Uma Bawang Residents' Association					✘
28	FORMADAT: The Alliance of the Indigenous Peoples of the Highlands in the Heart of Borneo		✘			
29	Slow Food International		✘			
30	Customary Community of Dayak Iban in Sungai Utik Longhouse		✘			
31	FoMMA, Alliance of the Indigenous Peoples of the Kayan Mentarang National Park		✘			
32	Lore Lindu Biosphere Reserve (LLBR)					✘
33	The Nature Conservancy		✘			
34	YTM		✘			
35	Agency for planning and development (BAPPEDA: Badan Perencana Pembangunan Daerah)					✘
36	Water catchment agency (BPDAS: Badan Pengelolaan Daerah Aliran Sungai)		✘			
37	Forest observation agency (BPKH: Balai Pemantapan Kawasan Hutan)	✘				
38	World Network of Biosphere Reserves (WNBR)					✘
39	UNESCO					✘
40	The Climate, Community and Biodiversity Alliance, or CCBA)		✘			
41	Koltiva			✘		
42	Bujang Raba		✘			
43	The Landscapes and Livelihoods Group			✘		
44	Astara Capital			✘		
45	Satelligence			✘		
46	Remote Sensing Solutions			✘		
47	Open Forests			✘		
48	Smart Conservation Tools					✘
49	South East Asia Rainforest Research Partnership (SEARRP)				✘	

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