CHALLENGE & COLLABORATION

A decade of the
Independent Peat Expert Working Group

Published December 2025

CONTENTS

1 — **About This Report**
3 — **Leadership Messages**
6 — **Context & Legacy**
8 — **Expert Advice**
12 — **Scientific Research**
18 — **Next Steps**
22 — **References**

THIS REPORT IS DEDICATED TO THE MEMORY OF MARK WERREN AND ANTHONY GREER – TWO INVALUABLE COLLEAGUES WHOSE CONTRIBUTIONS TO IPEWG AND ITS WORK WITH APRIL ARE IMMENSE. WE MISS THEIR WISDOM, THEIR DEDICATION AND THEIR FRIENDSHIP.

1

ABOUT THIS REPORT

The Independent Peat Expert Working Group (IPEWG) is one of two external advisory bodies established under APRIL's Sustainable Forest Management Policy 2.0 in 2015. Made up of national and international peatland scientists, IPEWG's mandate is to help APRIL fulfill its commitments to manage its peatland concessions responsibly, informed by the best science.

This report reviews ten years of that advisory function and the creation, with IPEWG's guidance, of APRIL's world-class in-house peatland science research capacity. It also looks forward to the evolution of IPEWG's role through the direct inclusion of one of its members on the independent Stakeholder Advisory Committee. The report concludes with a series of recommendations from the IPEWG members for APRIL (members pictured below).

Dr. Ruth Nussbaum
IPEWG Coordinator and Director of Proforest

Prof. Supiandi Sabiham
Bogor Agricultural University (IPB), Indonesia

Prof. Chris Evans
UK Centre for Ecology and Hydrology, Bangor

Prof. Susan Page
University of Leicester, UK

Dr. Fahmuddin Agus
National Research and Innovation Agency (BRIN), Indonesia

Prof. Dwi Astiani
University of Tanjungpura, West Kalimantan, Indonesia

About **Leadership Messages** Context & Legacy Expert Advice Scientific Research Next Steps References

2

LEADERSHIP MESSAGES

CHANGE THROUGH SCRUTINY AND COLLABORATION

Dr Ruth Nussbaum

IPEWG Coordinator and
Director of Proforest

A decade on from APRIL's decision to set up an expert working group to advise on its responsible peatland management, it is easy to forget what a leap of faith that was for all concerned. Despite the company's landmark pledge in 2015 to no-deforestation in its concessions and supply chain, there was scepticism in many quarters about how deep its commitment to sustainability really was. Respected scientists could be forgiven for worrying whether the watchdog they were being invited to join would have any real teeth.

APRIL's own move also required courage. Lots of companies set up advisory groups. What was highly unusual here was the degree of freedom we were given to collaborate with the in-house science team and the access given to any data we wanted to see. Even more unprecedented was the requirement, embedded within the newly launched

Left: *IPEWG receiving a briefing at APRIL's Kerinci site in Riau Province*

sustainability policy, for operational management teams to consult with the newly established IPEWG prior to any significant operational actions in APRIL's peatland concessions.

There was good faith on all sides, but it took time to figure out how the company and its expert group would work together. To begin with, there were inevitable missteps and a healthy tension, but over time trust grew, aided by the first secretariat led by Tim Fenton. Both APRIL's management and the IPEWG scientists started to realise how powerful the collaboration could be in terms of APRIL's own peatland management, as well as spreading knowledge and good practice among the peatland science community more broadly.

The building blocks for that trust were the quality and professionalism of the company's peatland science team and the support they received from company leadership. That support came in the form of state-of-the-art equipment and infrastructure such as the four Eddy Covariance Flux Towers that the company established to accurately measure greenhouse gas emissions from different landscapes. But also, in the commitment to long-term monitoring studies involving years of data collection at hundreds of sites across its peatland forestry and conservation areas.

That body of high-quality peatland science has formed a solid basis for IPEWG's advice on operational decisions, such as plans for new canal infrastructure. I'm particularly proud of the group's support for translating the outputs of that research to inform operational practice in real time. That involved building a good working relationship with APRIL's operations team and I'm grateful for their constructive engagement as we helped APRIL to operate more sustainably on peatland based on the best available science.

Above: *IPEWG members at their final meeting in Kerinci in October 2025*

Another vital contribution was to nudge the company towards even greater transparency. This encouraged the peatland science team to share their work at dozens of scientific meetings and conferences to the benefit of the Indonesian and international scientific community. IPEWG members have also collaborated with the researchers to publish the findings in world-class scientific journals. That research has contributed significantly to our understanding of tropical peatlands.

Over time, the relationship between IPEWG and APRIL has evolved from watchdog to scientific partner. We still offer scrutiny and challenge when appropriate, but our expertise and the company's own science has become embedded in the way APRIL operates. Standard Operating Procedures now incorporate that science, and there is a much greater recognition within the company of the importance of integrating operational needs with protecting nature and working with local communities. In other words, IPEWG's contribution has, to a large extent, become institutionalised within APRIL.

That is not to ignore the huge challenges that remain in managing peatlands in the face of a changing climate and evolving scientific understanding, but APRIL has laid robust foundations. As IPEWG's scrutiny function evolves to a new phase, I have no doubt that the principles of seeking a balance between production, protection and social development while minimising further loss or degradation of peat are now firmly embedded within APRIL's operating model.

I am very grateful for the hard work of the company's management and operational teams as well as to my IPEWG colleagues in building a productive and impactful collaboration. As you will read in the pages that follow, a great deal has been achieved. I look forward to watching the company build on that progress in the decade to come.

About **Leadership Messages** Context & Legacy Expert Advice Scientific Research Next Steps References

CONNECTING SCIENCE, POLICY AND PRACTICE

Lucita Jasmin

Group Director of Sustainability, RGE

One of APRIL's core tenets is that our landscape management is carried out with a sound scientific underpinning. Where there are gaps in the science, we make investments to address them and where we need advice, we aim to bring in the best people to provide it.

With responsible peatland management at the heart of our 2015 Sustainable Forest Management Policy 2.0 (SFMP 2.0), we knew that both new research and advice would be required. Peatland is a sensitive and special landscape that acts as an immense store of carbon. More than half of APRIL's operational footprint was on peatland and external stakeholders wanted reassurance that we could manage it responsibly.

SFMP 2.0 set out the principles, but we needed access to the right expertise to help us put that into practice. That meant finding the best experts from within the region and across the world, but we also needed advisors who understood the Indonesian context and the challenges of working in a developing economy.

We were incredibly fortunate that leading Indonesian peatland expert Professor Supiandi Sabiham plus respected international scientists Prof Chris Evans, Prof Sue Page, Prof Vincent Gauci, Dr Ruth Nussbaum and Prof Annamari Laurén agreed to join the group in 2016. Jonathan Wootliff acted as the group's coordinator in its first year.

Those early meetings were not easy. IPEWG members were very clear that to support us fully, they needed and expected to be provided with detailed information on company operations. Understandably, there was some internal resistance to allowing external experts see our data, challenge our processes and question our operational practices.

But we recognised early on that if IPEWG were to be successful, there would need to be a marked shift in how we engaged with external experts. Both the IPEWG members and internal stakeholders realised there was a unique opportunity to further improve how the company operates responsibly on peatlands by driving world class research and using this to inform on-the-ground operational practices.

Over the past ten years of working closely with IPEWG, we can say with certainty that they have been a key driver of change in our peatland management. Their constructive and critical inputs have helped APRIL develop our highly competent peatland science team and they have supported operational best practice to align with global standards.

The upcoming handover of IPEWG's responsibilities to a formal role within the Stakeholder Advisory Committee is the next phase of its evolution and APRIL's continued commitment to being a leader in responsible peatland management.

**Director of Sustainability and External Affairs at APRIL Group 2015-2025 before moving to her current role at APRIL's parent company RGE*

3

CONTEXT & LEGACY

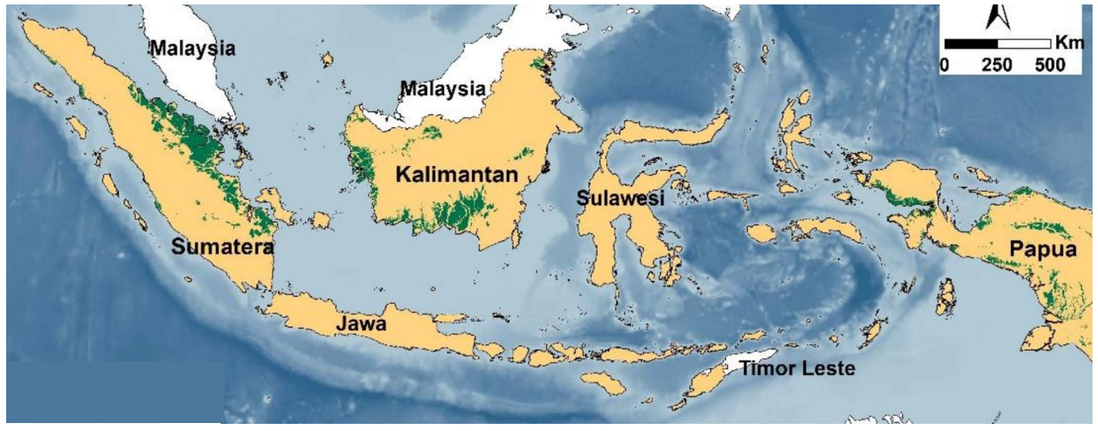
Peatlands are rare and unique wetland ecosystems covering around 3 to 4 percent of the Earth's land surface in both the tropics and higher latitudes (Xu, J. et al., 2018). Despite their relatively small area globally, they contain up to a third of the world's soil carbon — an estimated 450 to 650 gigatons. That is twice the amount of carbon found in the world's forests (Scharlemann, J. P. W. et al., 2014).

That vast carbon store is being depleted due to drainage and other impacts. In Southeast Asia for example, peat swamp forests and mangroves combined make up just 5.4 percent of land area but are estimated to account for around half of all emissions from land use (Sasmito, S. D. et al., 2025).

Most of that total is in Indonesia, which stores around 7 percent of global peatland carbon — 36 gigatons (Anda, M. et al., 2021; Widyatmanti, W., et al., 2022).

In Indonesia, a significant proportion of peatland has been converted from its natural state since the 1990s with 7.8 million hectares now managed for agriculture and silviculture. Of that total, more than one million hectares have been converted to predominantly *Acacia crassicarpa* fibre plantations. The majority of this broader land conversion happened outside of industrial-scale concessions, predominantly by smallholder farmers (Wijedasa, L. S., et al., 2018).

Riau Province on the central eastern coast of Sumatra– where a significant proportion of APRIL's operations are located – covers an area of 8.9 million hectares, of which 45 percent are peatlands. Less than 1 million hectares of these peatlands remained forested by 2015 (Miettinen, J. et al., 2016). This remains the largest area of peatlands in Indonesia (Anda, M. et al., 2021).



Above: *Indonesia peatland distribution map, (Yuwati, T. W. et al., 2021)*

Indonesia · Other Countries · Peatland

Globally, peatland degradation, excluding fires, is releasing around 2 gigatons of CO_2 equivalent per year, according to the Global Peatlands Assessment (Kopansky, D. et al., 2022). That amounts to around 4 percent of anthropogenic emissions — more than the aviation and shipping sectors.

Southeast Asia is home to around 24 million hectares of tropical peatland (Kopansky, D. et al., 2022).

In recent years, the government has brought in policies to mitigate peatland degradation and fire as a result of oil palm, pulpwood crops and logging (Osawa, T. & Binawan, A., 2023). In 2011, it imposed a moratorium on new licenses for the establishment of those crops on primary natural forests and peatland. This no-deforestation measure was initially temporary, but it has since been extended three times and eventually made permanent by President Joko Widodo in 2019.

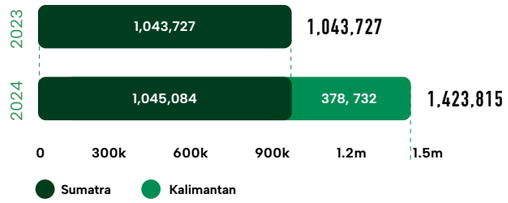
About Leadership Messages **Context & Legacy** Expert Advice Scientific Research Next Steps References

APRIL'S COMMITMENTS

APRIL acknowledges its past role in the legal and licensed conversion of 249,053 ha of natural peatland landscapes in Riau Province and elsewhere to industrial plantation. It has since made a series of commitments to halt further conversions and now sets aside a significant portion of its concessions for nature conservation and rehabilitation.

In 2014, APRIL introduced its 1-for-1 pledge to conserve and restore an area of natural forest equal in size to its plantation concessions. Its conservation and restoration land is currently 465,886 ha. That's around 77 percent the size of its plantation forests, which including both peat and mineral soil cover 607,084 ha in total (APRIL Sustainability Report 2024). Of the 597,593 ha of concessions on peatland, the proportion managed for conservation (54.6 percent or 326,328 ha) is higher.

Managed Area Overview By Region (Ha)

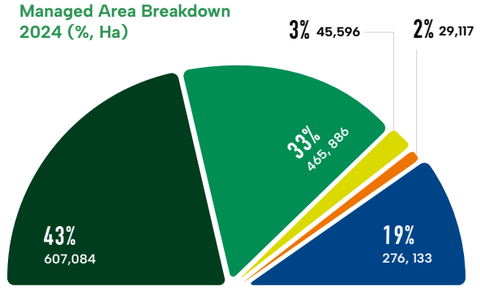


Note: *IPEWG's role only covered APRIL's concessions on Sumatra.*

APRIL is responsible for managing approximately 4 per cent of the total peatland area in Indonesia. Of this area, 271,265 ha are plantation and 326,328 ha are conservation and restoration areas (APRIL Sustainability Report 2024). The most valuable portion of peatland forest in biodiversity terms that the company is conserving is the more than 150,000 ha Restorasi Ekosistem Riau (RER) project that has been running for over 10 years.

Under its Sustainable Forest Management Policy 2.0 (SFMP 2.0), which was activated in June 2015, the company halted all harvesting of mixed hardwoods, committing to only receive plantation grown supply. It's "no-deforestation" commitment also enforced a moratorium on natural forest clearance on land deemed of High Conservation Value (HCV) or High Carbon Stock (HCS). These commitments also applied to suppliers and the company put in place a rigorous due diligence process, assured annually by KPMG PRI, to prevent it sourcing wood from suppliers that had carried out deforestation after this date.

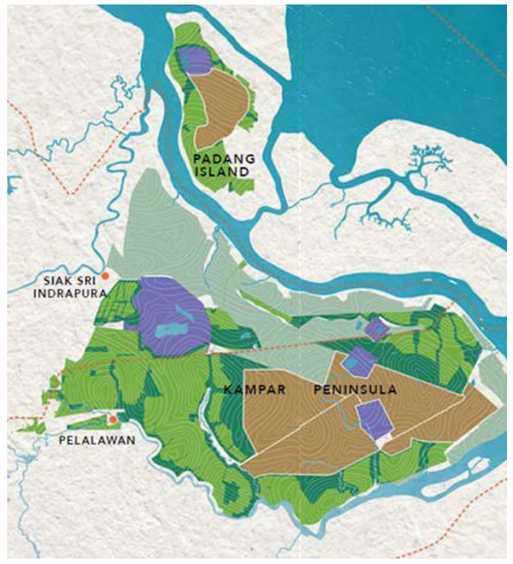
Managed Area Breakdown 2024 (%, Ha)



TOTAL: 1,423,816

Developed Forest Plantations (Commercial) · Conservation Areas · Community Fibre Plantations · Infrastructure · Others

- ***'Managed areas'*** *include our 12 PT RAPP concessions and 35 long-term supply partners in Riau and Kalimantan*
- ***'Others'*** *includes de facto unmanageable areas within our land footprint due to inoperable soils (e.g. rocky terrain or flood-prone areas), community claims under review, boundary overlaps and village settlement areas*
- *Fluctuations on total managed hectarage can occur year-on-year due to boundary revisions based on ground verification and digital spatial analysis tolerances*



Restorasi Ekosistem Riau (RER) · APRIL Conservation · Conservation Area · APRIL Plantation · Other Companies

Above: *Map showing extent of Restorasi Ekosistem Riau with APRIL plantations around it in Riau Provice, on the central eastern coast of Sumatra*

About Leadership Messages Context & Legacy **Expert Advice** Scientific Research Next Steps References

4

EXPERT ADVICE

Aside from the landmark no deforestation commitment, SFMP 2.0 also laid out APRIL's commitment to "implement best practices on peatland management". To assist in these efforts, the policy committed APRIL to create a Peat Expert Working Group. Its job would be to provide "inputs and recommendations" on international best management practices on peatland, the actions required to ensure conservation of forested and critical peatland landscape, and development options for non-forested peatland. Crucially, SFMP 2.0 stipulated that no canal construction or maintenance could be undertaken without detailed input from the expert group.

To signify its objectivity, the six-member group became known as the Independent Peat Expert Working Group or IPEWG ahead of its launch in early 2016. It is currently comprised of three British and three Indonesian experts.

IPEWG's Terms of Reference emphasised the group's independence and impartiality, and set out the imperative for APRIL to publish scientific data as well as for transparency and constructive engagement with external stakeholders such as NGOs.

The new members came together for their first meeting in January 2016 with an initial two-year mandate. Alongside detailed discussions about how the group would operate, recommendations on specific management issues and requests for data from APRIL, the group resolved to "build a body of work that will truly support APRIL's objective to be the world leader in responsible peatland management." It requested that the company use IPEWG's expertise holistically, "to guide strategic decision-making on the management of their peatland concessions" (1st IPEWG Summary Report, 2016).

The group began work at pace, with eight meetings in the first two years and a rapidly growing scientific agenda. Joe Lawson, then chair of APRIL's Stakeholder Advisory Committee routinely attended meetings, providing a vital link with that oversight body. Likewise, APRIL's senior management were present at most meetings along with occasional invited participants from organisations such as Wetlands International, The Nature Conservancy, Deltares and Badan Restorasi Gambut (BRG), Indonesia's peatland restoration agency.

A key document that set the direction of travel for the group's work was presented at IPEWG's fourth meeting in November 2016. This was the first iteration of the APRIL-IPEWG Peatland Roadmap and Work Plan (IPEWG, 2017). It was developed by the expert group to provide a framework for the development of a long-term, science based, peatland management strategy.

Once refined, it provided a template for IPEWG's interactions with APRIL and the minutes of subsequent meetings — which were published openly — were arranged to follow its format. The roadmap had three core components: Science-based understanding and minimising impacts; Responsible Peatland Operations; and The Vision for Peatland Landscapes. The work plan led to APRIL's Peatland Strategy which was concluded in 2022.

Any significant developments by APRIL on peatland had to be presented to IPEWG first for feedback. At times, IPEWG requested extra data or asked for changes to the plans to reduce their impact on, for example, nearby conservation areas. Resolving these issues often took detailed discussions and sometimes meant planned developments needed to be delayed or undergo costly modification. Over time though, the operational teams adjusted their approach to anticipate potential IPEWG objections. That meant it was possible to agree agree new plans without extensive discussion because proposals were already closely aligned with expectations from the expert body.

The company also sought IPEWG's input when formulating the relevant sections of the APRIL2030 agenda — a series of detailed commitments and targets on climate, nature and people.

MEETINGS BY YEAR

2016 4 IN PERSON

21–23 Jan	Pangkalan Kerinci
29 Apr – 2 May	Pangkalan Kerinci
19–23 Aug	Singapore
1–4 Nov	Pangkalan Kerinci

2017 4 IN PERSON

7–10 Mar	Pangkalan Kerinci and Jakarta
16–17 May	Pangkalan Kerinci and Oxford
8–9 Sep	Pangkalan Kerinci, Jakarta and Oxford
28 Nov – 1 Dec	Pangkalan Kerinci

2018 2 IN PERSON

6–8 Jun	Pangkalan Kerinci
6–9 Nov	Pangkalan Kerinci

2019 2 IN PERSON, VARIOUS ONLINE

25–27 Mar	Pangkalan Kerinci
22 – 24 Oct	Pangkalan Kerinci

2020 VARIOUS ONLINE

Online meetings only due to the pandemic

2021 VARIOUS ONLINE

Online meetings only due to the pandemic

2022 1 IN PERSON, VARIOUS ONLINE

6–10 Jun	Pangkalan Kerinci

2023 1 IN PERSON, VARIOUS ONLINE

22–26 May	Pangkalan Kerinci

2024 1 IN PERSON, VARIOUS ONLINE

26–30 Apr	Pangkalan Kerinci

2025 1 IN PERSON, VARIOUS ONLINE

20–21 Oct	Pangkalan Kerinci

COOPERATION AND COMPROMISE

Mark Holmes

Head of Fibre Operations

Prior to the adoption of SFMP 2.0 and the establishment of IPEWG, APRIL's peatland management approach was guided by silvicultural best practices, with the primary objective of optimizing yield across plantation cycles. This included active regulation of water tables within compartments and detailed mapping of key topographical features across the landscape. To support this, an interconnected system of canals was used to serve multiple functions such as facilitating water table depth adjustment, providing effective means of transport, and acting as perimeter boundaries to reduce external fire risk.

However, APRIL's early practices primarily focused on operational efficiency, with less focus and attention to the long-term biophysical consequences of intensive drainage. Sustained lowering of the water table, without sound water management practices and guidelines, while beneficial for short-term plantation growth, accelerates peat oxidation and compaction, resulting in subsidence and release of greenhouse gases. Over decades, this subsidence poses significant challenges for water management, increases flood risk in low-lying areas, and reduces the long-term viability of plantation operations.

The creation of IPEWG helped us to integrate a broader perspective, focusing both on operational efficiency and on the mid- to long-term impacts of plantation activities and canal systems on the wider landscape. The expert group specifically raised questions on how water zoning and canal infrastructure may influence peat subsidence trajectories, the hydrological integrity of natural forest blocks, and the sustainability of surrounding community livelihoods.

Engagement between APRIL's Fibre team and IPEWG has been consistently professional and constructive, but the process of expert review and feedback initially required adjustment. At first it wasn't always comfortable, but it has proven to be an essential step in demonstrating our commitment to responsible peatland management under SFMP 2.0.

The requirement to address IPEWG's technical queries and concerns strengthened the rigour of our internal planning, approval, and documentation processes. It also positioned us to respond more effectively to external stakeholder reviews, as many of the issues raised by IPEWG aligned closely with those of customers, NGOs, and community representatives.

Over time, the review process became more efficient and embedded into routine operations. For example, proposals for new estate perimeter boundaries required robust justification of their necessity, supported by risk assessments of unmanaged or previously encroached areas. Similarly, any canal construction adjacent to High Conservation Value (HCV) areas, natural forests, or community agricultural land was subjected to hydrological impact analysis to demonstrate that these areas would not be adversely affected by altered water flows or increased subsidence risk.

Beyond enhancing awareness of peatland science, IPEWG has contributed to strengthening APRIL's peatland management approach. Regular collaboration between IPEWG members and APRIL's Peatland Science team has supported ongoing research and field validation, ensuring that operational practices are informed by the latest scientific insights. This collaboration not only improved our technical understanding but also shaped the refinement of our Peatland Strategy.

Furthermore, IPEWG's guidance has reinforced the importance of broader stakeholder engagement, encouraging APRIL to extend dialogue and knowledge-sharing across the wider landscape, beyond plantation boundaries. I am grateful to IPEWG for the spirit of collaboration and partnership that they brought to our interactions. APRIL's peatland operations are more sustainable as a result.

5

SCIENTIFIC RESEARCH

Achieving APRIL's vision of responsibly managed peatland landscapes that contribute to Indonesia's climate goals and sustainable development requires a solid scientific underpinning. A rigorous understanding of the carbon, subsidence and water dynamics of the tropical peatland landscapes APRIL manages is particularly important.

When the company formally embarked on its peatland science programme in 2015, applicable data on greenhouse gas emissions and hydrology from tropical peatlands was limited. Few high-quality field studies had been carried out in the region, and the data that did exist was frequently incomplete, meaning that it was open to wide and sometimes conflicting interpretation.

To address this problem and achieve its aims, APRIL needed to reduce the knowledge gap in three critical areas of science: greenhouse gas emissions, peat subsidence and their links with landscape hydrology. The company also needed credible baseline data on emissions from different landscapes to support its goal of reaching net-zero emissions from land use by 2030. These are all areas where IPEWG has supported and encouraged investments in robust, long-term research.

APRIL's in-house peatland science team now comprises 25 people, including three PhDs and six at Masters level. In collaboration with IPEWG, the team regularly presents research findings at scientific conferences around the world including the International Union of Forest Research Organizations World Congress, the American Geophysical Union Fall Meeting and the European Geosciences Union General Assembly. The team also publishes in some of the world's leading scientific publications including Nature and Nature Geoscience.

Key to the team's research on greenhouse gas balance was the installation of four Eddy Covariance Flux Towers — 40 to 48 metre-tall structures that carry state-of-the-art equipment for measuring carbon dioxide, methane and other variables high above the forest canopy — on the company's licensed concession areas. Erected between October 2016 and November 2019, three of the towers are sited on peatland plantation, conservation forest and degraded forest areas and one on mineral soil plantation to allow comparison between different landscape types. That investment in high-quality equipment, long-term monitoring and in-house expertise is unprecedented in comparable agriculture and silviculture companies, and ranks among the most advanced greenhouse gas flux monitoring infrastructure on peatlands anywhere in the world.

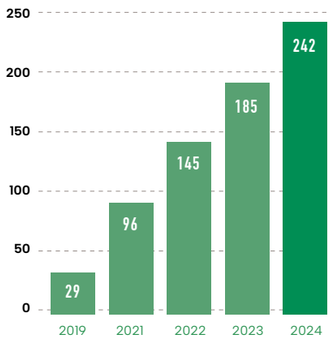
The benefits of that research have not been confined to APRIL. With regular encouragement and assistance from IPEWG members, the company's science team has made the results available to the global scientific community. All data that support the greenhouse gas flux findings have been archived on Zenodo, a general-purpose open research repository managed by CERN (Deshmukh, C. S., 2023). Some datasets have also been submitted to AsiaFlux, a regional science network for sharing land emissions data. Publishing the findings in respected scientific journals has also been a priority.

Above: *Careful control of water levels is essential to minimise peat subsidence and carbon emissions.*

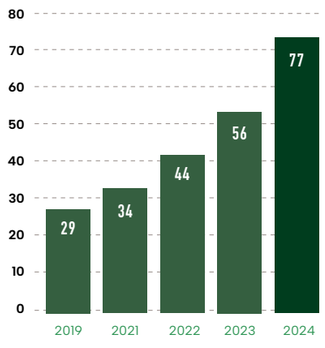
About Leadership Messages Context & Legacy Expert Advice **Scientific Research** Next Steps References

PEATLAND SCIENCE

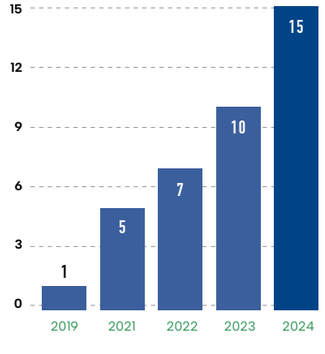
Cumulative No. of Collaborations



Cumulative No. of Dialogues, Workshops and Conferences Attended



Cumulative No. of Peer-Reviewed Scientific Publications



RESEARCH AND METHODOLOGY

SUBSIDENCE AND HYDROLOGY

Peatland subsidence occurs when groundwater levels drop, causing a combination of compaction and decomposition of peat above the water level and consolidation of peat below the water. Given the low-lying nature of Southeast Asian tropical peat landscapes, the magnitude of future subsidence rates will determine their susceptibility to flooding and the economic sustainability of managed peatlands.

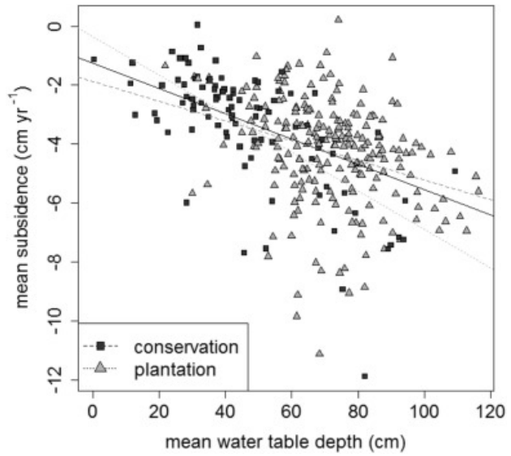
In Northern latitudes where peatlands have been subject to long-term drainage — such as in the Netherlands, Northern Germany, Eastern England, the San Joaquin Delta in California and Southern Florida — there has been subsidence of several metres. That has left agricultural land lying well below sea level presenting significant management problems.

Peat drainage in Indonesia is a much more recent phenomenon, with most silviculture and agriculture established since the 1990s. Here, the long-term rates of subsidence and potential for mitigation or prevention are much less well understood.

IPEWG members and APRIL researchers collaborated on two research papers (Evans, C. D. et al., 2019; Evans, C. D. et al., 2022) that have used data from 434 sites within the company's plantations (319 sites) and conservation forest (115 sites) in Riau Province. The unique data set is by far the largest ever published on peat subsidence and includes valuable data from 62 sites that have been continuously monitored since 2007.

The data shows that subsidence averaged 4.3 cm per year in *Acacia crassicarpa* plantations (Evans, C. D. et al., 2019). Subsidence rates are similar within 300 metre forest buffer zones surrounding plantation areas, but lower in forest areas that are more distant from the plantations.

The rate of subsidence in *Acacia* plantations is reducing over time. In 2007 it was 4.89 cm per year, but that dropped to 3.74 cm per year by 2018 (Evans, C. D. et al., 2022). That aligns with research on subsidence in high-latitude peatlands and recent tropical peatland studies.



***Above**: Mean measured rate of subsidence and water table depth for all individual measurement sites. Solid line shows the best fit line of a linear regression fitted to all data (n = 318), short dashed line show fit to native conservation forest sites (n = 92) and long dashed line fit to Acacia plantation sites (n = 220). Figure originally published in Evans, C. D. et al., 2019.*

The data also shows that subsidence rate is highly dependent on water table depth (with a lower water table associated with more rapid subsidence), which was more influential than peat depth, plantation age or vegetation type. The rate increased significantly during the severe drought period in 2015-16 associated with the El Niño Southern Oscillation and Indian Ocean Dipole (Evans, C. D. et al., 2022). Taken together these results emphasise the need for diligent water management and highlight the impact of extreme dry periods on the natural peat forest ecosystem.

GREENHOUSE GAS FLUX

In their research to monitor greenhouse gas flux, the peatland science team, in collaboration with IPEWG, investigated the net exchange of CO_2 and methane, as the balance between emissions and uptake, across different landscape types — specifically *Acacia* plantation, intact peat swamp forest and degraded peat swamp forest. Additionally, they track the flux of nitrous oxide in and out of the soil. This approach provides a more comprehensive understanding of the greenhouse gas dynamics in these ecosystems.

The gold standard methodology for capturing the complete range of emissions and absorption from an ecosystem is to take measurements high above the canopy using an Eddy Covariance Flux Tower. This methodology involves instruments at the top of the tower taking precise readings of wind speed and gas concentration in the air many times a second and averaging them out to create an overall flux measurement.

Apart from the four towers established by APRIL, published data exist for only five others in Indonesia (Burba, G., 2019). There are another eight towers in Malaysia and Brunei. Between them, North America and Europe have nearly 1500 flux tower sites.

Combined with estimates of the carbon lost from the ecosystem in water and tree harvesting, the team has been able to construct an accurate picture of the total carbon dynamics of the system in each of the locations.

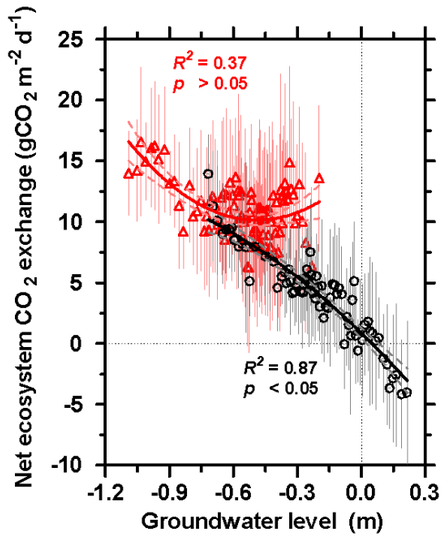
The strong drought signal in the subsidence data is also present in the data from the flux towers. In one study, the team compared CO_2, methane and nitrous oxide emissions from the intact forest and the degraded site. In both, ground water level was crucial to the greenhouse gas balance with more net carbon dioxide released into the atmosphere when the water level dropped (Deshmukh, C. S. et al., 2021).

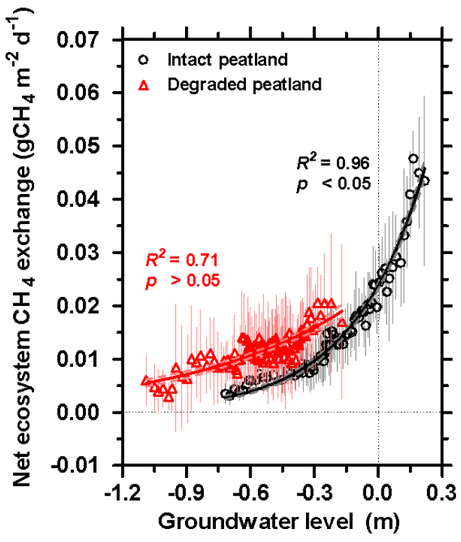
There was also an important difference indicated between the sites. Taking all the gases together there was a net export into the atmosphere of 20 tonnes of CO_2 equivalent per hectare each year in the intact forest within the RER ecosystem restoration area. That compares with 43.8 tonnes of CO_2 equivalent per hectare per year at the degraded site, more than double the rate of the natural forest (Deshmukh, C. S. et al., 2021).

This finding emphasises the importance of conserving existing peatland forest by preventing logging, burning and other degradation. It also indicates that there are significant potential carbon gains from the rehabilitation and restoration of degraded areas.

An earlier study published by the peatland science team looked specifically at methane emissions from the natural forest and the plantation — one of the first eddy covariance methane exchange data sets ever reported for any tropical

peatland. Again, the results showed that water level is key, but for methane, net emissions increase when ground water is higher due to an increase in anaerobic breakdown of organic matter by microbes. Comparing the two sites, the intact forest released more methane annually (9.1 g of methane per square metre) than the plantation forest (4.7 g of methane per square metre) (Deshmukh, C. S. et al., 2020). This figure is also higher than previous estimates used by the Intergovernmental Panel on Climate Change (IPCC).





***Above**: The ground water level is a key driver of the net ecosystem exchange for both carbon dioxide and methane. Figure originally published in Deshmukh, C. S. et al., 2021.*

The results highlight that tropical peatlands are significant sources of methane. They also illuminate a balance with CO_2 emissions mediated by ground water. In wetter conditions tropical peatlands release less CO_2 but more methane, while the opposite happens in drier conditions. Ton-for-ton, methane has a more powerful warming effect than CO_2, though the results above show that when factored together, the far larger amounts of CO_2 overwhelm the climate forcing impact of the methane.

CARBON DYNAMICS OF A FULL CROP ROTATION

Finally, the most comprehensive evaluation of the data from the flux towers to date builds on the earlier studies with a comparison of three sites — *Acacia* plantation, intact peat swamp forest and degraded peat swamp forest. It incorporated measurements of net ecosystem exchanges of CO_2 and methane as well as soil nitrous oxide flux taken between October 2016 and May 2022. The multi-year measurements are crucial because they incorporate a full rotation of the *Acacia* crop from planting to harvesting.

It is, to the team's knowledge, the first investigation of greenhouse gas flux in any peatland-based fibre plantation globally to cover a full plantation-rotation period and encompassing all major carbon inputs and outputs (Deshmukh, C. S. et al., 2023).

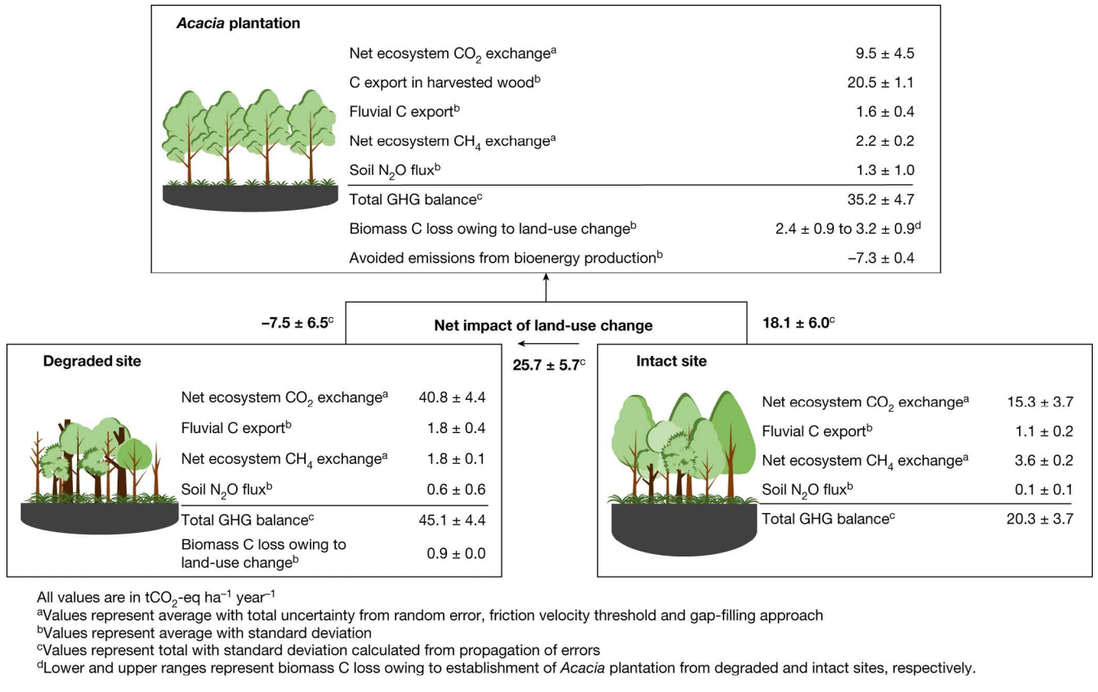
The results confirmed the earlier comparison between the intact and degraded site, but now with more data. The more comprehensive results indicate that intact peatland forest is emitting greenhouse gases at an annual rate of 20.3 tonnes of CO_2 equivalent per hectare, while the rate from the degraded site is 45.1 tonnes of CO_2 equivalent per hectare. Averaged over a full rotation cycle, the level of emissions from the *Acacia* plantation sits between the two, 35.2 tonnes of CO_2 equivalent per hectare.

That number assumes that the carbon removed from the land in the form of timber that is converted to pulp and subsequently into products like paper and textiles, makes its way into the atmosphere when these products eventually break down. However, some of the biomass removed from the land is consumed in APRIL's pulp mill to generate energy to run the production process, something that is standard practice in the industry. By displacing coal power, doing so avoids emissions of 7.3 tonnes of CO_2 equivalent per hectare per year, which can be considered to offset some plantation emissions.

Taken together, and including biomass carbon loss owing to land-use change, these results allow a more precise accounting of the impact of changes in land use on greenhouse gas flux:

- The establishment of *Acacia* plantation on a degraded forest site results in a reduction in long-term greenhouse gas emissions of 7.5 tonnes of CO_2 equivalent per hectare per year. The results highlight that degraded peat swamp forest is the worst performing of the three landscape types.
- Conversion of an intact peatland forest site to *Acacia* plantation results in a long-term net increase in greenhouse gas emissions of 18.1 tonnes of CO_2 equivalent per hectare per year.
- The avoided emissions by conserving peatland forest and preventing it from being degraded are 25.7 tonnes of CO_2 equivalent per hectare per year.

One surprise from the results was the emissions figure for the *Acacia* plantation. The IPCC cites a much higher figure for that land use of 73 tonnes CO_2 equivalent per hectare per year — the so-called Tier 1 Emissions Factor (Drösler, M. et al., 2013). The discrepancy may be because that figure came from studies using the more limited soil chamber and subsidence methodology, most of which were undertaken soon after the plantations were established, when they may have been larger CO_2 sources. The lower figure means that *Acacia* plantations have about half the climate impact as had been previously thought.



All values are in tCO_2-eq ha^{-1} $year^{-1}$
[a]Values represent average with total uncertainty from random error, friction velocity threshold and gap-filling approach
[b]Values represent average with standard deviation
[c]Values represent total with standard deviation calculated from propagation of errors
[d]Lower and upper ranges represent biomass C loss owing to establishment of *Acacia* plantation from degraded and intact sites, respectively.

***Above:** Comparing greenhouse gas emissions at three different peatland sites. The bold numbers indicate net impact of land-use change. Positive values indicate net emissions to the atmosphere and negative values indicate avoided emissions. Figure originally published in Deshmukh, C. S. et al., 2023.*

OTHER RESEARCH

Aside from the published data, IPEWG has requested and monitored other research strands designed to inform APRIL's responsible peatland management practices.

- One early line of inquiry was to better understand the factors that contribute to fire risk. In November 2016, IPEWG recommended that APRIL "systematically analyse and review all APRIL data and information on … fire occurrence and management". That data showed there was no evidence of a strong correlation between water table depth and fire in APRIL's concessions. Instead, limited evidence suggested that the main correlation was with fuel moisture and that rapid response to fire was an equally or more important factor in preventing large-scale blazes.

- Another area of focus for IPEWG has been supporting APRIL in identifying ways to reduce plantation carbon emissions and subsidence by maintaining a higher water table. Driven by both regulatory and environmental considerations, the research was supported by modelling using the MIKE-SHE hydrological modelling system and the Plantation Simulator developed principally by Prof Annamari Laurén, an early member of the expert group. This study aimed to understand the implications of raised water levels on plantation productivity and peat health.

Above and Right: *IPEWG scientists have made regular field visits to observe peatland management practices and research*

APRIL and IPEWG agreed two experimental approaches. In 2017, they finalised plans for a water table manipulation field trial that would monitor tree growth at water table depths of 30 cm, 50 cm and 70 cm over a total area of about 35 hectares. A complementary initiative was a smaller-scale lysimeter trial that was designed to provide a more controlled and detailed understanding of the effects of water table depth. That setup involved two bounded and sealed plots measuring 30 m by 20 m. Heavy plastic walls were installed in the peat and driven 50 cm into the mineral soil base to create a watertight "box" within which water depth could be precisely controlled at either 40 cm or 80 cm.

- Other approaches that have been pursued by APRIL and reported to IPEWG are ongoing genetic research to identify *Acacia crassicarpa* varieties that are more tolerant of wetter peat and investigating alternative native species crops.

Further research in these and other areas will support meaningful progress toward the company's peatland management goals (see IPEWG's Final Recommendations).

About Leadership Messages Context & Legacy Expert Advice **Scientific Research** Next Steps References

BUILDING A FOUNDATION OF WORLD-CLASS SCIENCE

Dr Chandra Deshmukh

Senior Science Advisor – Climate and Carbon, APRIL Peatland Science

The collaboration with IPEWG has been hugely beneficial to the company's internal peatland science team which I lead. They have pushed us further and helped us to achieve a body of research that is internationally recognised and of real value for guiding APRIL's responsible peatland management.

I joined the company in 2016 around the time the expert group was being established. My first formal interaction with them was shortly after, at their second meeting at Pangkalan Kerinci in April 2016, a few months into their first mandate.

As was typical for these meetings, there were detailed discussions about ongoing and future research priorities. These included an assessment of progress on the three greenhouse gas flux towers that were already under construction, as well as a briefing on APRIL's ongoing peat soil research work streams.

It was immediately clear to me that the experts on the group were much more than high-level advisors who would offer occasional comment while sipping a hot latte in the chill of an air-conditioned room. They wanted to get their boots in the peat, engage with the data and act as practical research partners.
That hands-on approach was vital, but I'd highlight three other important aspects of the partnership. First, IPEWG's expertise was vital for research prioritisation. A decade ago, there were much larger gaps in tropical peatland science, but we needed to decide which were the most urgent and operationally relevant questions to answer.

Second, they approached their science remit as a collaboration with both internal company stakeholders and others outside. That helped to align all parts of the company behind a coherent and focused research agenda.

Lastly, they played a key role in building APRIL's internal research capacity, both in terms of technical expertise and opening doors to scientific collaborations, conferences and publications. These efforts have also supported the Indonesian peatland science community more broadly.

Over time, that clear and focused research agenda has produced results in the form of a series of high-profile scientific publications. Recognition has also grown beyond Indonesia, with the peatland science team regularly participating in international meetings and hosting the AsiaFlux annual meeting in October 2025 — a prestigious gathering of the regional research network.

In short, success bred success. The IPEWG partnership has helped create a solid research framework that is an important legacy of the past decade. Peer-reviewed science is now central to how we work, as it gives our actions credibility and ensures our impact is measurable.

Building on those foundations, the scope of our research ambition is now evolving. For the last decade, the peatland science team has been focused on understanding the core dynamics of the peatland landscapes in Sumatra: principally hydrology, greenhouse gas emissions and subsidence.

In the coming years, our broader research agenda will seek to understand the landscape mosaic more holistically. That will take in biodiversity monitoring, conservation, habitat rehabilitation, ecosystem services and socio-economic factors among other things. The research collaborations and friendships made with the IPEWG members will, I have no doubt, continue to play a vital role.

6

NEXT STEPS

A NEW CHAPTER

Prof Fahmuddin Agus

National Research and Innovation Agency (BRIN), Indonesia

The six peatland science experts who make up IPEWG came together for our 16th and final in-person meeting in October 2025. Fittingly, we were gathered at APRIL's operations in Kerinci, which was playing host to the annual AsiaFlux conference at which researchers from around the world, including APRIL's own peatland science team, shared cutting-edge work.

APRIL, with IPEWG's support, has achieved a huge amount in the decade since the group's first meeting in January 2016 in terms of advancing tropical peatland science and making APRIL's operational management practices more sustainable (I joined later in 2019). Though IPEWG will no longer convene in its current form, that momentum and spirit of collaboration combined with rigorous independence and challenge will carry through into the next phase.

Importantly, the fundamental watchdog function that IPEWG performs will remain in place. I will take up a position on the Stakeholder Advisory Committee, whose expertise spans forestry, ecology and soil health, community agriculture, corporate social responsibility, and public policy. I will strengthen the SAC with my background on sustainable peatland management and greenhouse gas inventory. The SAC pre-dates IPEWG and oversees the implementation of the company's Sustainable Forest Management Policy 2.0 (SFMP 2.0) and its subsequent APRIL2030 commitments and targets.

Under the new configuration, APRIL's operational teams will now be obliged to consult with the SAC before carrying out any significant developments in peatland concessions. My SAC colleagues and I will scrutinise those plans and provide feedback.

As with IPEWG previously, this will happen in the open. SAC meetings are minuted and those records are published online. They also frequently include outside observers. One advantage of the new arrangement is that there will be an opportunity to assess the company's plans with a more interdisciplinary perspective, including the social and economic aspects of the broader peatland landscape beyond APRIL's concessions.

The core science of water management, nutrient flows and greenhouse gas emissions dynamics will remain crucial. In this respect, I will continue to work with the former IPEWG members as required on specific issues where their expertise would be valuable. Interaction with the company's own impressive in-house peatland science team will be strengthened. There will be no dilution of our ability to provide the collaboration and challenge required to support APRIL's responsible peatland management.

The priorities for this next phase will be to help APRIL's leadership to continue to maintain the high standards they have set themselves. That means striving for even better alignment with the commitments set out in SFMP 2.0 to manage peatland concessions to world-class standards. It means helping them to achieve the ambitious target they set as part of the APRIL2030 agenda to achieve net zero emissions from land use by the end of the decade. It means working even more closely with the communities who surround APRIL's concessions to prevent fires. And it means continuing to do first-rate research that can be published in the scientific literature to the benefit of scientists around the world. I look forward to working with my expert colleagues to help APRIL achieve those aims.

About Leadership Messages Context & Legacy Expert Advice Scientific Research **Next Steps** References

IPEWG'S FINAL RECOMMENDATIONS

The following are recommendations for ongoing and future actions by APRIL to keep improving the sustainability and responsible management of their peatland concessions.

• APRIL's in-house research capacity is world-class and a huge asset. Maintaining its openness is vital. We recommend that the company continue to expand this capability in support of its responsible peatland management goals and sustainability commitments. Continuing to publish scientific data and collaborating with researchers around the world will benefit both the company and the wider understanding of tropical peatland science.

• Participation in and organisation of scientific conferences are also an effective means for disseminating research and receiving feedback from broader national and international audiences. We recommend their continuation.

• There is an opportunity to use conservation and restoration areas outside of RER but within APRIL's concessions more effectively as sites for biodiversity recovery and peat regeneration. Recent research carried out on peatland elsewhere in Sumatra indicates that forest species can recover spontaneously following canal blocking and rewetting (Hooijer, A., et al., 2024). We recommend that APRIL pursue research to complement and improve the active management of its conservation areas to maximise carbon storage benefits and biodiversity rehabilitation.

• The wide-ranging climate change risk assessment carried out by APRIL in 2023 and 2024 delivered key insights into likely future impacts and vulnerabilities. We recommend more detailed work to convert those strategic insights into specific peatland management actions that balance emissions against carbon sequestration and storage. There may be opportunities to identify marginal plantation land that will be increasingly prone to flooding. Targeting that land for rewetting would enhance native species regrowth and possible new peat formation, sequestering CO_2 and contributing to the company's Net Zero land use target and the 1-for-1 conservation commitment.

• The data are clear that raising the water table in plantations reduces subsidence and carbon emissions, though there is a trade-off against fibre productivity. We recommend that APRIL continue to pursue research into plantation management at higher water tables, and in potential future climatic conditions with increased flooding events. We urge the company to continue investigating genetic varieties of *Acacia crassicarpa* that are more productive in peat with a higher water table.

• The RER conservation area represents a significant carbon store but, as the Nature paper published by the in-house science team in collaboration with members of IPEWG established, in recent years it appears to have been a net source of CO_2 (Deshmukh, C. S. et al., 2023). The precise reasons for that are not established and require further research. Subject to that research, we recommend that APRIL explore management options that will reduce the net outward carbon flux from the natural forest so that RER can act as a more effective "insetting" option to balance higher emissions from production areas.

• There are gaps in the broader understanding of the socio-economic context of the landscape that APRIL operates within. We recommend more research into how local communities surrounding the company's concessions pursue their livelihoods while contributing to broader responsible peatland management goals. We also encourage efforts by the company to work even more closely with local communities on fire management, peat regeneration, biodiversity conservation and utilising peatland for agriculture responsibly.

Above: *IPEWG travel by helicopter to visit a remote field location*

REFERENCES

Anda, M. et al. (2021) Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. Geoderma, Vol 402, 115235. DOI: 10.1016/j.geoderma.2021.115235

APRIL Sustainability Report 2023: Striving for Excellence.

APRIL Sustainability Report 2024: Staying the Course.

Burba G. (2019) Illustrative Maps of Past and Present Eddy Covariance Measurement Locations: II. High-Resolution Images. DOI: 10.13140/RG.2.2.33191.70561

Deshmukh, C. S. et al. (2020) Impact of forest plantation on methane emissions from tropical peatland. Global Change Biology, Vol. 26, 2477-2495. DOI: 10.1111/gcb.15019

Deshmukh, C. S. et al. (2021) Conservation slows down emission increase from a tropical peatland in Indonesia. Nature Geoscience, Vol. 14, 484-490. DOI: 10.1038/s41561-021-00785-2

Deshmukh, C. S. et al. (2023) Net greenhouse gas balance of fibre wood plantation on peat in Indonesia. Nature, Vol. 616, 740-746. DOI: 10.1038/s41586-023-05860-9

Deshmukh, C. S. & Agus, F. (2023) Greenhouse-gas effects of land-use change in Indonesian peatlands. Nature. Research Briefing 6th April 2023. DOI: 10.1038/d41586-023-00944-y

Deshmukh, C. S. (2023) Net greenhouse gas balance of fibre wood plantation on peat in Indonesia (v.03) [Data set]. Zenodo. DOI: 10.5281/zenodo.7728463

Drösler, M. et al. in 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (eds Hiraishi, T. et al.) 2.1–2.79 (IPCC, 2013).

Evans, C. D. et al. (2019) Rates and spatial variability of peat subsidence in *Acacia* plantation and forest landscapes in Sumatra, Indonesia. Geoderma, Vol. 338, 410-421. DOI: 10.1016/j.geoderma.2018.12.028

Evans, C. D. et al. (2022) Long-term trajectory and temporal dynamics of tropical peat subsidence in relation to plantation management and climate. Geoderma, Vol. 428, 166100. DOI: 10.1016/j.geoderma.2022.116100

Hooijer, A., et al. (2024) Benefits of tropical peatland rewetting for subsidence reduction and forest regrowth: results from a large scale restoration trial. Scientific Reports, 14:10721. DOI: 10.1038/s41598-024-60462-3

IPEWG (2017) Implementing APRIL's 4Cs on Peatland. APRIL-IPEWG Peatland Roadmap. Version 3.2, June 2017

Kopansky, D. et al. (2022) Global Peatlands Assessment: The State of the World's Peatlands. UN Environment Programme.

Miettinen, J. et al. (2016) Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. Gobal Ecology and Conservation, Vol. 6, 67-78. DOI: 10.1016/j.gecco.2016.02.004

Osawa, T. & Binawan, A. (2023) Selling Peatland for the Future: History, Land Management, and the Transformation of Common Land in Rantau Baru. In: Okamoto, M., Osawa, T., Prasetyawan, W., Binawan, A. (eds) Local Governance of Peatland Restoration in Riau, Indonesia. Global Environmental Studies. Springer, Singapore. DOI: 10.1038/s41467-025-55892-0

Sasmito, S. D. (2025) Half of land use carbon emissions in Southeast Asia can be mitigated through peat swamp forest and mangrove conservation and restoration. Nature Communications, Vol. 16, 740. DOI: 10.1038/s41467-025-55892-0

Scharlemann, J. P. W. et al. (2014) Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Management Vol. 5(1), 81–91. DOI: 10.4155/cmt.13.77

Widyatmanti, W., et al. (2022) Codification to secure Indonesian peatlands: From policy to practices as revealed by remote sensing analysis. Soil Security, Vol. 9, 100080. DOI: 10.1016/j.soisec.2022.100080

Wijedasa, L. S., et al. (2018) Carbon emissions from South-East Asian peatlands will increase despite emission-reduction schemes. Global Change Biology, Vol. 24, 4598–4613. DOI: 10.1111/gcb.14340

Xu, J. et al. (2018) PEATMAP: Refining estimates of global peatland distribution based on a meta-analysis. CATENA, Vol. 160, 134-140. DOI: 10.1016/j.catena.2017.09.010

Yuwati, T. W., et al. (2021) Restoration of degraded tropical peatland in Indonesia: A review. Land, Vol. 10, 1170. DOI: 10.3390/land10111170

Right: *During field visits, IPEWG members frequently use boat access to reach plantations and conservation sites on peatland*