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CHAPTER 22

Conservation status, governance challenges and the path to integrated landscape management of Peat Swamp Forests in Peninsular Malaysia

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Abstract: Peat Swamp Forests (PSF) were once among Malaysia's most extensive wetland ecosystems, and remain critically important for biodiversity conservation, carbon storage, hydrological processes, and sustainable resource use. Historically, they occupied about 2.56 million ha, equivalent to nearly 8% of Malaysia's land area and roughly 720,000 ha or 5.45% of the land area in Peninsular Malaysia. The PSF areas in Peninsular Malaysia declined by 66% from an estimated 670,000 ha in 1981 to 226,000 ha in 2010. Between 2010 to 2026, the PSF area declined further 5% to an estimated 192,788 ha in 2026. PSFs are habitat to a large number of rare, threatened, and endangered (RTE) species, with many specially adapted to its unique acidic wetland environment. Their specialised plant communities support a wide range of animal species, including 140 species of fish, with more than 60 blackwater species restricted to this habitat in Peninsular Malaysia. In the past half-century, PSFs have been logged, cleared, drained, burnt, and developed for other commercial uses, especially oil palm plantations. PSF areas have been totally lost or reduced to less than 1% in Kelantan, Perak and Negeri Sembilan, while only 3.5% remain in Johor; extensive PSFs only persist in Selangor and Pahang with an estimated total area of 170,000 ha. While PSF areas have declined in all states between 2010 to 2026, the significant increase in Selangor reflects the success of proactive conservation measures leading to reduced fires and enhanced forest recovery. Successful conservation measures developed for PSFs in Selangor are now being introduced in Pahang and Johor. The montane peatland forest of Pahang have also been recently documented. This chapter highlights governance and resourcing issues, as well as key challenges, opportunities, and policy recommendations to further enhance the conservation of PSFs in Peninsular Malaysia.

INTRODUCTION

General overview: A landscape of water, carbon and complexity

Peat swamp forests (PSFs) originally covered 2.56 million ha or nearly 8% of the land area of Malaysia, and about 720,000 ha or 5.45% of the land area of Peninsular Malaysia (DOE 2019b). They are naturally waterlogged lowland tropical rainforests growing on deep accumulations of organic soil known as peat, receiving water primarily from rainfall with minimal input from groundwater or surface water (Takada *et al.* 2016). This rain-fed or ombrotrophic character gives peat swamp forests their distinctively nutrient-poor and highly acidic nature, setting them apart from other wetland forest types across the region (Page *et al.* 2012).

Peat is composed of approximately 10% solid organic matter and 90% pore space (DOA 2023). Under persistently waterlogged conditions, these pores remain saturated, creating oxygen-poor environments that maintain the peat in an anaerobic state. In this state, microbial activity and organic matter decay are significantly reduced, allowing carbon-rich

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plant material to accumulate over long periods of time. Peat accumulates when organic matter addition exceeds breakdown, typically at only 0.5 to 3 millimetres per year (DOE 2019a; Parish *et al.* 2019). In Malaysia, peat soil is formally defined as having organic matter content exceeding 65% and depth greater than 50 cm (DOA 2023; Paramananthan *et al.* 2018). Maintaining a water table within 10 – 30 cm of the surface is critical, as any lowering of this threshold transforms the peat environment from to an aerobic state, thereby introducing oxygen into the peat profile and accelerating oxidative decomposition. This process increases carbon emissions, land subsidence and renders the highly combustible peat layer increasingly vulnerable to fires and prolonged smouldering combustion (Che Azmi *et al.* 2021).

Peatlands in Malaysia are recognised as Environmentally Sensitive Areas (ESA) under the Section 6B of the Town and Country Planning 1976 (Act 172), in the National Physical Plan 4 (NPP 4) (Rengasamy and Parish 2021), and the Guidelines for Planning and Management of Environmentally Sensitive Areas (PLANMalaysia, 2025). The peatland area in Peninsular Malaysia and estimated remaining peat swamp forest, according to state, is given in Table 1 and illustrated in Figure 1.

Table 1. Estimated area of peatlands and remaining peat swamp forest in Peninsular Malaysia.

State	Area of peatlands (ha)*	% against Total Peatland in PM	Area of PSF in 2010 (ha) (WI-2010)+	Area of PSF in 2026 (ha) (GEC)++	% of PSF area in 2026 against Total Peatland in each state
Federal Territories (Kuala Lumpur and Putrajaya)	383	0.05	44	25	6.53
Johor	187,151	26.00	16,304	6,386***	3.41
Kelantan	7,692	1.07	5,626	80	1.04
Negeri Sembilan	6,220	0.86	1,729	0	0.00
Pahang	201,693**	28.02	129,759	102,773	50.96
Perak	75,124	10.44	4,574	300	0.40
Selangor	173,198	24.06	16,231	73,224	42.28
Terengganu	68,338	9.49	51,579	10,000	14.63
TOTAL	**719,799**	**100**	**226,021**	**192,788**	**26.78**

Data source:

* Department of Agriculture (2023); Department of Environment (2019a).

** Including upland peat data from Department of Agriculture (2024).

*** Data from assessment of PSF in Johor in 2023-2025 by GEC and Johor State Forestry Department.

+ WI (2010) refers to Wetlands International (2010) using a parameter of 70% tree cover.

++ GEC refers to data collected and analysis in 2026 undertaken by Global Environment Centre for this paper using satellite imagery and ground truthing for Selangor and Pahang States and Satellite imagery for other states.

It can be seen that between 2010 to 2026, the area of peat swamp forest in Peninsular Malaysia has declined by 15% from 226,021 in 2010 to 192,788 in 2026. The area of PSF in all states declined except for Selangor that showed a significant increase. The increase in Selangor can be attributed to recovery in PSF after the logging moratorium imposed in 2010, as well as fire prevention and restoration action especially in NSPSF from 2008 onwards. The decline in the other states is linked to extensive logging, land conversion, drainage and fires. It may also be linked to the smaller size and fragmented nature of the peatlands in these states making them more vulnerable to degradation.

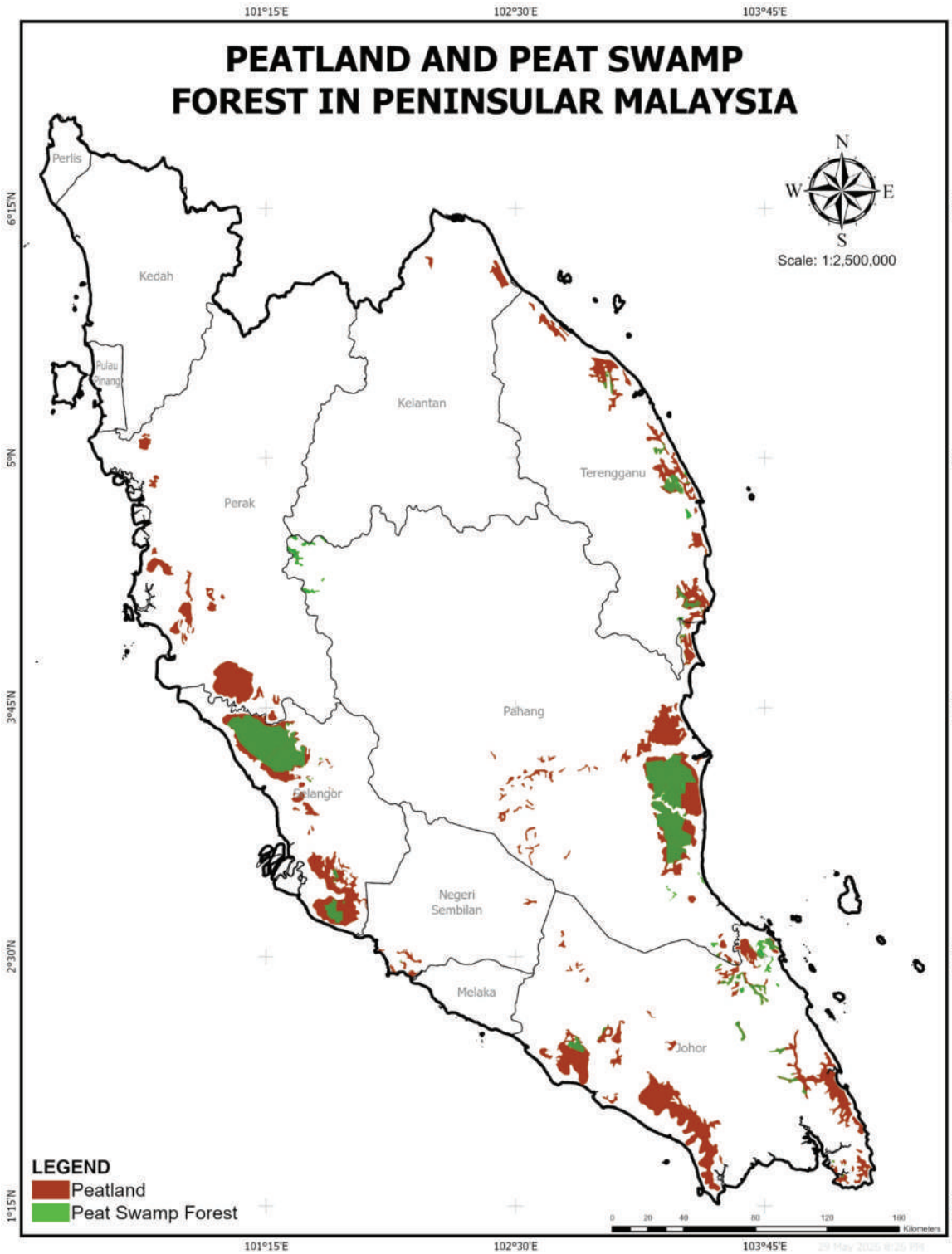

Figure 2. Extent of peatlands and remaining peat swamp forests in Peninsular Malaysia (Source: peatland extent from DOA 2019 and 2024; PSF from this study).

Types of peatlands and peat swamp forest

There are two main types of peatlands and peat swamp forest formed based on altitudinal gradients (DOA 2023). Lowland peat in Peninsular Malaysia occurs under inundated or waterlogged conditions normally in coastal or riverine lowlands at an altitude of 1 – 100 m a.s.l., whereas upland peat is normally found above 1500 m in non-inundated conditions and confined to limited areas with high rainfall.

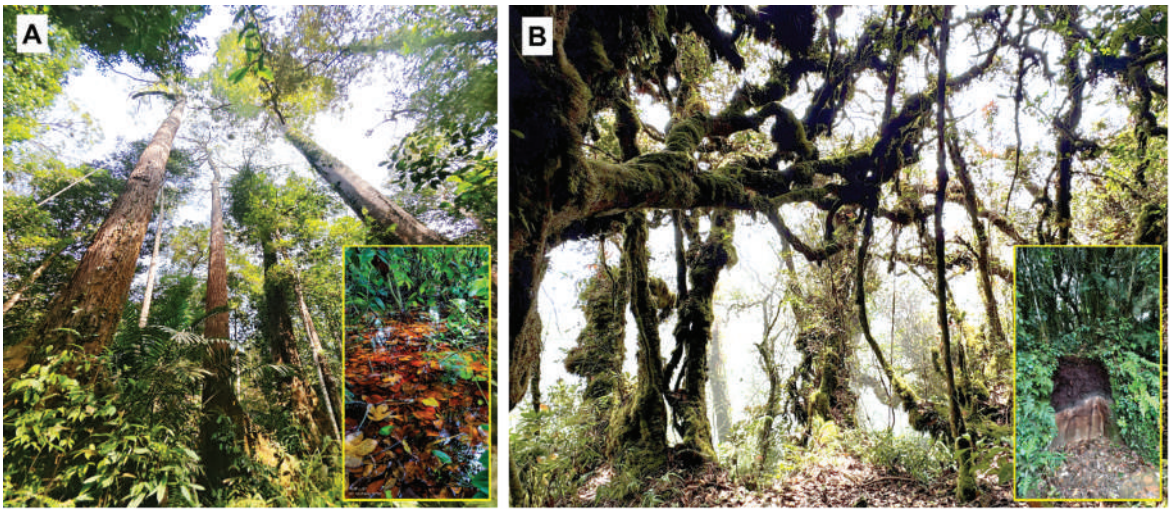

Figure 2. (A) lowland peat swamp forest (Kuala Langat South Forest Reserve, Selangor) and **(B)** upland/montane peat forest (Mossy Forest, Cameron Highland, Pahang) across different altitudinal gradients in Peninsular Malaysia.

Lowland peat swamp forests

Lowland peatlands can be divided further into topogenous and ombrogenous peatlands. Topogenous peatlands occur in depressions in the landscape such as river valleys or lake basins, while ombrogenous peatlands develop in floodplains between adjacent lowland river valleys.

Ombrogenous peatlands

In Peninsular Malaysia, ombrogenous lowland peat swamp forests developed primarily through post-glacial geomorphological and hydrological processes in former coastal lagoons and deltaic plains located between major river systems. The underlying peat typically forms a dome-shaped structure, with peat depth generally increasing progressively from the margins towards the centre, ranging from approximately 3 to 10 metres deep (DOE 2019a), and is commonly underlain by clay or sandy mineral substrates. Water in these systems is highly acidic, with pH ranging from 3.5 to 5.0, while having a distinctive dark-brown-to-black colouration due to high concentrations of dissolved humic substances derived from partially decomposed organic matter (DOA 2023).

Figure 3 illustrates the formation of ombrogenous peat swamp forests in low-lying coastal or riverine basins where drainage is poor and water tends to accumulate. Over time, continuous waterlogging creates anaerobic conditions that slows down the decomposition of plant material such especially wood and roots. This leads to the gradual build-up of partially decomposed organic matter, forming a thick layer of peat. As this peat layer deepens, it influences forest structure and hydrology, resulting in a unique ecosystem adapted to permanently wet, nutrient-poor and acidic conditions typical of lowland peat swamp environments (DOE 2019a).

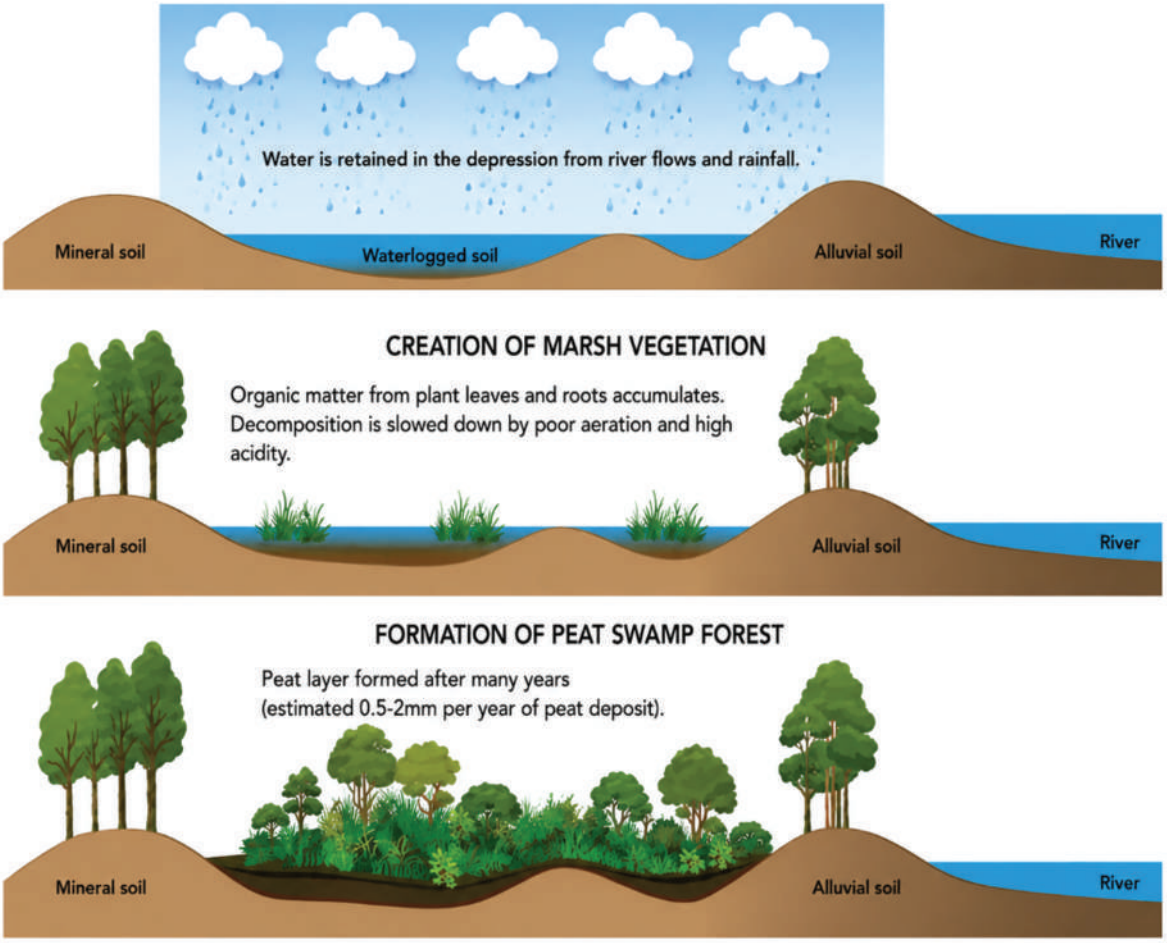

Figure 3. Cross-sectional diagram of a dome-shaped lowland peat deposit illustrating peat formation processes. [Modified from DOE (2019a)].

These forests exhibit distinct vegetation adapted to the unique peatland environment, with a characteristic three-layered canopy structure. Typical species include *ramin melawis* (*Gonystylus bancanus*), *meranti paya* (*Rubroshorea platycarpa*), *jelutong* (*Dyera polyhylla*) and *geronggang* (*Cratoxylum arborescens*): all well adapted through buttress roots, aerenchyma tissues and specialised seed dispersal mechanisms (Giesen *et al*. 2018).

Topogenous peatland

Topogenous peatland, also known as river valley or lake basin peatlands, develop in inland depressions, along river channels, or within and around lake basins where the water table is high. Sediment accumulation or tectonic activity may reduce drainage efficiency, resulting in persistently elevated water levels that create permanent swamp conditions conducive to peat formation. In Peninsular Malaysia, these peatlands occur mainly in the Bera district of Pahang, particularly at Bera Lake. These peatlands receive water inputs from surrounding low hills, making them relatively more mineral- and nutrient-rich compared to ombrotrophic peatlands. As a result, they support distinct vegetation communities adapted to high water tables, including palms, sedges, and other swamp species as well as areas of peat swamp forest. They also occur to a limited extent in other locations where topography restricts inflowing water from nearby hills and in areas adjacent to ombrotrophic peat domes.

Upland and montane peatland

At elevations exceeding 1,000 metres a.s.l., cooler temperatures, high rainfall, and reduced evapotranspiration slow decomposition sufficiently to allow upland or montane peat formation (Page and Baird 2016). At Cameron Highlands, Pahang, upper montane, cloud or mossy forest exists at 1,500 to 2,000 metres a.s.l. along the top of the Titiwangsa Mountain Range, where organic soil accumulates to depths of 1 to 3 metres beneath a canopy of moss-draped and gnarled trees as shown in Figure 4. These upland peat ecosystems are typically characterised by persistently moist conditions, low nutrient availability, and slow nutrient cycling rates, which collectively favour long-term organic matter accumulation (Osman 2018). An estimated 6,000 to 10,000 ha of upland peat is found in Cameron Highlands. Patches of upland peat are also believed to occur elsewhere along the Titiwangsa Range at Frasers Hill and Genting Highlands, but no comprehensive survey has been undertaken yet.



Figure 4. Field photograph and cross-section of highland peat formation at Gunung Brinchang, Cameron Highlands. Photo credit: Global Environment Centre (GEC).

Both lowland and upland peat systems store carbon at densities far exceeding dryland forests. The waterlogged and anaerobic conditions within peat soils enable the long-term sequestration and storage of large quantities of organic carbon accumulated over thousands of years (Page and Baird 2016). When drained or disturbed, this stored carbon is rapidly oxidised and released into the atmosphere as carbon dioxide, thereby contributing significantly to greenhouse gas emissions and climate change. Consequently, the conservation and sustainable management of peat swamp forests constitute a strategic national priority in supporting Malaysia's commitment to achieving net-zero greenhouse gas emissions by 2050 (Varkkey *et al.* 2024).

ECOSYSTEM FUNCTIONS OF PEAT SWAMP FORESTS IN PENINSULAR MALAYSIA

Carbon storage and climate regulation

Peat swamp forests are among the most carbon-dense terrestrial ecosystems on Earth, because carbon is stored not only in above-ground biomass but also in substantial below-ground pools, including living root biomass and long-term accumulated organic matter in peat soils (Pan *et al*. 2024). Globally, peatlands store more than 550 billion tonnes of carbon, representing approximately 30% of soil carbon worldwide (Parish *et al.* 2021),

while Southeast Asian deposits alone hold an estimated 68.5 billion tonnes (Page *et al.* 2011). Findings from the North Selangor Peat Swamp Forest show that median below ground peat carbon stocks reach approximately 1,401 tonnes per hectare, with stocks approximately twelve times higher than above ground biomass carbon pools (Brown *et al.* 2023). Drained or disturbed tropical peatlands are persistent net sources of greenhouse gases. Such emissions directly undermine national climate mitigation commitments, including Malaysia's net-zero emissions aspiration by 2050 under the national climate framework.



Figure 5. Endangered, Rare and Threatened (ERT) Peat Swamp Forest tree species from Peninsular Malaysia. Note: CR – Critically Endangered; EN – Endangered; NT – Near Threatened; VU – Vulnerable.

Hydrological regulation
Intact peat swamp forests function as natural water reservoirs within lowland catchments, absorbing rainfall and releasing it gradually to sustain river flows during dry periods while moderating peak flood events. This buffering capacity contributes to catchment-scale hydrological stability and water security. Coastal peatlands in Selangor and Johor serve as critical ecological buffers preventing saltwater intrusion into freshwater systems and agricultural land (Polgar and Jaafar 2018), particularly under conditions of rising sea levels and land subsidence. Where these peatlands have been drained, hydrological alteration has led to soil subsidence, increased fire susceptibility, reduced water retention capacity and enhanced saline intrusion in coastal zones. These impacts have long-term implications for potable water supply, agricultural productivity, infrastructure stability and community livelihoods (Parish *et al.* 2021).

Biodiversity and socioeconomic value
Peninsular Malaysia's peat swamp forests support highly specialised, evolutionarily adapted and often endemic species assemblages, making them globally significant for conservation (Posa *et al.* 2011). According to the International Union for Conservation of Nature (IUCN), many of these species are listed in the Red List of Threatened Species (IUCN 2025), underscoring the urgent need for their conservation and protection as a matter of utmost priority. The North Selangor Peat Swamp Forest alone harbours more than 60 threatened species, including Malayan tapirs (*Tapirus indicus*, Endangered), sun bears (*Helarctos malayanus*, Vulnerable), smooth-coated otters (*Lutrogale perspicillata*, Vulnerable), and leopards (*Panthera pardus*, Endangered) (Sasidhran *et al*. 2016). Critically threatened tree species (Figure 5) include *ramin melawis* (*Gonystylus bancanus*, Critically Endangered), *meranti paya* (*Rubroshorea platycarpa*, Endangered), and *jelutong* (*Dyera polyhylla*, Vulnerable). Endemic blackwater fish species including *Betta persephone* (Endangered), *B. livida* (Endangered), *B. tomi* (Endangered), and *B. tussyae* (Endangered) are confined exclusively to these habitats. Beyond biodiversity conservation, these forests sustain local communities through timber, non-timber forest products, fisheries, and ecotourism, making their conservation both an ecological necessity and a long-term socioeconomic imperative.

SITUATIONAL ANALYSIS: A LEGACY OF DRAINAGE AND FRAGMENTED GOVERNANCE

Over the past five decades, a significant portion of Peninsular Malaysia's peat swamp forests have been systematically cleared, drained, and converted for a wide range of purposes, including agricultural cultivation, plantation development, settlement expansion, and infrastructure construction (Parish *et al.* 2021). While these land use changes contribute to national and state economic development, they have generated severe and compounding ecological consequences. Drained peatlands subside at rates of 2 – 5 cm per year, depending on drainage intensity and land use type (Wösten *et al*. 2008; Hooijer *et al*. 2012). Continued subsidence increases flood exposure, reduces land elevation relative to sea level in coastal areas, and elevates infrastructure damage and disaster risk.

The peat swamp forests of Peninsular Malaysia have undergone especially rapid reduction since 1981 as shown in Table 2. It is assumed that all peatlands (719,799 ha) in Peninsular Malaysia (DOE 2019b) were originally forested. In 1981, 670,000 ha hectares (93%) was still thought to be forested (UNDP 2006). Thereafter, there was a rapid decline (66% decline in 30 years) until 2010, where when only 226,000 ha of relatively intact peat swamp forests was recorded (Wetlands International 2010). Since then, the area of peat swamp forests has declined at a slower rate of 1% per year with the current extent estimated as 223,425 ha. The changes between states however have not been even. However, the changes have not been even. In the last 15 years, the PSF areas have declined in Terengganu,

Negeri Sembilan and Pahang, but have increased in Selangor as a result of conservation measures. Of the remaining PSFs, about 94% is within designated the Permanent Reserved Forests, while with the remaining found within state land forests (Forestry Department of Peninsular Malaysia 2022).

Table 2. Change in area of PSF in Peninsular Malaysia.

Year	Estimated area of peat swamp forests (ha)	Reference
Original	719,799*	DOE, 2019b
1981	670,000	(UNDP, 2006)
1991	330,000	(UNDP, 2006)
2006	300,000	(UNDP, 2006)
2010	226,021	(WI, 2010)
2026	192,788	This paper

*Assuming all areas with peat soil were originally vegetated with peat swamp forest.
Case studies from different peatland landscapes in Peninsular Malaysia are given in Annex 1.

Conservation actions

As at 2009, almost all of the peat swamp forests within Permanent Reserve Forests were designated as production forests and subject to logging. However, in 2010, Selangor imposed a moratorium on further logging statewide and initiated a fire prevention and restoration programme in the PSF, which has led to an increase in the area of PSFs after 2015. In 2023, the Pahang State initiated a peatland conservation and forest carbon project in 96,569 ha of Southeast Pahang Peat Swamp Forest, which has led to the phasing-out of logging in the largest remaining peat swamp complex in Peninsular Malaysia.

The majority of peat swamp forests outside the forest reserves (on state land) have generally been heavily logged and converted to oil palm or other uses. In 2019, the National Land Council imposed a ban on further conversion of forest and peatlands for oil palm; conversions for other purposes still continue however. In recent years, several proposed development projects in PSF have been discontinued as a result of public pressure. In southern Selangor, the state government proposed to de-gazette 931 ha (97% of the forest) of the Kuala Langat North Forest Reserve (KLNFR) in February 2020 for a mixed development project (New Straits Times 2020). Following strong public and stakeholder opposition, the proposal was abandoned and almost all the reserve was re-gazetted in May 2023 (MalayMail 2023). In Terengganu, about 1,029 ha of virgin peat swamp forest, which had been degazetted from the Belara Forest Reserve in 2017 and leased to a private company under a 99-year agreement, was proposed for oil palm development in 2024. However, following significant public objection, the Environmental Impact Assessment (EIA) was subsequently rejected. Efforts to enhance the protection of this area are still ongoing with a multi-stakeholder workshop organised in June 2026 to identify priority conservation actions.

According to Malaysia's Fourth Biennial Update Report (BUR4), drainage-based land use on peatlands released an estimated 8 million tonnes of carbon dioxide in 2019 alone (Ministry of Natural Resources, Environment and Climate Change 2022). Beyond direct emissions, the lowering of water tables through drainage exposes deep peat layers to oxidation and fire, with studies confirming that degraded and unmanaged peatlands experience fire activity at rates more than 25 times higher than those recorded in intact peat swamp forests (Miettinen *et al.* 2017).

Governance context

A critical governance challenge further compounds these ecological pressures. Peatland management in Peninsular Malaysia is characterised by institutional fragmentation, overlapping mandates, and varying levels of coordination across sectors as well as limitations in dedicated restoration financing and structured multi stakeholder engagement, especially in decision-making (United Nations Environment Programme 2022). Forestry Departments manage peatland areas gazetted as Permanent Reserved Forests, while Department of Agriculture, Malaysian Palm Oil Board, land offices, local governments, private sector actors, and local communities manage peatlands located outside reserved forest boundaries under distinct regulatory frameworks and development priorities. This multi-agency arrangement reflects the broader federal-state governance structure of Malaysia, where land matters fall primarily under state jurisdiction. Critically, a significant area of degraded peatland outside Permanent Reserved Forests, particularly areas without active land use or formal gazettement, lacks clearly assigned long-term management responsibility, which may increase vulnerability to recurrent fire, invasive species encroachment, continued carbon loss, and unmanaged drainage. Clarifying institutional responsibility for such landscapes is therefore an important step toward effective restoration planning.

In order to address fragmented management across peatland landscapes, Integrated Management Plans (IMPs) have been developed for several peatland landscapes, including the Integrated Management Plan for the North Selangor Peat Swamp Forest (IMP-NSPSF) 2025-2034, the Integrated Management Plan for the South Selangor Peat Swamp Forest (IMP-SSPSF) 2025-2034, and the Integrated Management Plan for the Southeast Pahang Peat Swamp Forest (IMP-SEPPSF) 2026-2035 (Selangor State Forestry Department 2025a, 2025b; Pahang State Forestry Department 2026), as well as State Action Plans for Peatlands (SAPP) for Selangor and Pahang 2026-2035, and the Johor State Peat Swamp Forest Management Plan 2021-2030 (Johor State Forestry Department 2021). In addition, a National Action Plan for Peatlands (NAPP) is being prepared for 2026-2035, which is currently being finalised by the Ministry of Natural Resources and Environmental Sustainability.

Financial and resource allocation patterns

The fragmentation of peatland governance is starkly reflected in resource allocation patterns, particularly in fire management expenditure. In Pahang, peatland fires within the Southeast Pahang landscape have recurred regularly, with significant fire events in 2014 and 2019 associated with substantial suppression costs that exceeded investments in prevention and long-term restoration initiatives (Smith *et al.* 2018; GEC 2023). Across the three major peat swamp forest landscapes of Selangor, Pahang and Johor, fire incidents have periodically affected the South Selangor Peat Swamp Forest, the Southeast Pahang Peat Swamp Forest, and peatland areas in southern Johor. Available assessments suggest that recurring suppression expenditures have generally outpaced investments in prevention, hydrological restoration and landscape level peat management (Smith *et al.* 2018; GEC 2023).

This pattern contrasts with international best practice guidance, which recommends that more than 80% of peatland fire management resources be directed toward prevention and preparedness rather than suppression (ASEAN 2015). Such preventive approaches are widely regarded as more cost effective and environmentally sustainable in peatland landscapes. A further structural consideration is that national level peatland policy frameworks operate alongside state level land administration authority, which can create coordination challenges in ensuring consistent implementation, financing continuity and cross boundary restoration for degraded peatlands outside gazetted forest reserves across Peninsular Malaysia. Strengthened intergovernmental coordination mechanisms may therefore enhance policy coherence and implementation effectiveness.

CHALLENGES AND OPPORTUNITIES

A broad range of ecological, institutional and socioeconomic dynamics shape peat swamp forest management across Peninsular Malaysia. While each landscape exhibits unique local conditions, several cross-cutting challenges and emerging opportunities are evident. These are synthesised in Table 3 and organised around key thematic dimensions, including hydrology, governance, fire management, economics and community rights.

Table 3. Summary of key challenges and opportunities in peat swamp forest conservation across Peninsular Malaysia across five key themes.

Theme	Challenge	Opportunity
Hydrology	Drainage fragments peatland domes, triggers oxidation, subsidence and fire across multiple land uses within a single hydrological unit.	Peat Hydrological Unit (PHU)-based planning and canal blocking programmes as demonstrated at Raja Musa deliver measurable hydrological recovery.
Governance	No single agency holds comprehensive responsibility for any peatland landscape, creating chronic management gaps and resource fragmentation.	Integrated Management Plans for NSPSF and SSPSF (2025-2034) establish a formal multi-agency framework aligned with national and ASEAN policies.
Fire Management	Suppression costs consistently and substantially exceed prevention investment across Selangor, Pahang and Johor.	Community-based landscape and water level monitoring and FDRS-based warnings in NSPSF, SSPSF and SEPPSF demonstrate cost-effective fire prevention strategies.
Economics	Drainage-based land use generates short-term returns at the cost of long-term subsidence, flooding and carbon loss.	Paludiculture and Malaysia's Bursa Carbon Exchange (BCX) and REDD+ mechanisms provide viable financial alternatives to drainage-based land use.
Community Rights	Indigenous Peoples and local communities remain inadequately recognised in formal governance despite proven stewardship capacity.	Formalising co-management frameworks delivers measurable, cost-effective and socially equitable conservation outcomes.

Addressing these challenges requires a fundamental shift from reactive and fragmented management approaches toward proactive, landscape-scale governance supported by sustained and predictable financing mechanisms and strengthened, meaningful partnerships with Indigenous Peoples and local communities across Peninsular Malaysia's remaining PSFs within Permanent Reserved Forests and state lands.

POLICY RECOMMENDATIONS: A WAY FORWARD

Securing the long-term sustainability of Peninsular Malaysia's PSFs requires a decisive shift from fragmented and largely reactive management approaches toward integrated, proactive and adequately resourced governance across multiple levels of administration. The policy recommendations provided in Table 4 are organised around five core imperatives: protection, conservation, restoration, payment for ecosystem services and community wellbeing.

Table 4. Policy recommendations for improving peat swamp forest management in Peninsular Malaysia.

Imperative	Recommendation	Key actions
Protect and Manage	Adopt the Peatland Hydrological Unit (PHU) as the primary planning and regulatory boundary	Enshrine hydrological landscape boundaries in State Action Plans for Peatlands (SAPPs) and the revised National Action Plan on Peatlands (NAPP). Align all forestry, agriculture, water resources and local government mandates around shared peatland protection objectives. Strengthen enforcement against encroachment and illegal drainage within and adjacent to gazetted peat swamp forest reserves.
	Mainstream peatland protection into national and state planning frameworks	Reflect peatland objectives explicitly in the 13th Malaysia Plan, National Physical Plan, State Structure Plans, REDD+ land use planning, agricultural development policies and national wetland frameworks. Ensure that sectoral development decisions do not undermine the hydrological integrity of peatland landscapes across Peninsular Malaysia.
Conserve	Establish a coordinated cross-sectoral governance framework	Formalise the National/State Peatland Working Committees and National/State Peatland Steering Committees as long-term, active inter-agency coordination platforms at both federal and state levels. Develop and gazette State Action Plans for Peatlands for all states with significant peat swamp forest coverage including Selangor, Pahang and Johor.
	Strengthen baseline data, monitoring and research	Invest in systematic biodiversity assessments, peat depth mapping, carbon stock measurement and hydrological monitoring across all major peat swamp forest landscapes. Integrate remote sensing, GIS mapping and community-based monitoring into a national peatland observatory framework to support evidence-based adaptive management.
Restore	Rebalance expenditure from fire suppression to fire prevention and restoration	Allocate at least 80% of state fire management budgets to preventive measures including hydrological restoration, canal blocking, rewetting, early warning systems and community fire monitoring, in line with international best practice (Association of Southeast Asian Nations, 2015). Treat restoration investment as essential long-term infrastructure rather than exceptional post-disaster expenditure.
	Implement integrated landscape restoration through PHUs	Scale-up canal blocking, rewetting and natural regeneration programmes across degraded peat landscapes in Selangor, Pahang and Johor, using the 6R approach of rewetting, reduction of fire, revegetation, revitalisation, reporting and monitoring as well as resource mobilisation as the operational framework for restoration planning and implementation.

Payment for Ecosystem Services	Develop and activate carbon finance and PES mechanisms for peat swamp forests	Accelerate the development of verified carbon projects within intact and restoring peat swamp forest landscapes, utilising Malaysia's Bursa Carbon Exchange (BCX) and international REDD+ mechanisms. Establish payment for ecosystem services frameworks that compensate state governments, forest managers and private landowners for maintaining hydrological integrity, carbon stocks and biodiversity values.
	Develop a long-term peatland investment framework to 2035	Formulate a 10-year financing strategy drawing on public budgets, private sector contributions, green bonds, carbon finance and international development cooperation to ensure sustained and predictable funding for peatland protection, restoration and management across all states in Peninsular Malaysia.
Community Wellbeing	Formalise and fund community co-management as standard practice	Legally recognise and financially support local and Orang Asli communities as frontline peatland guardians through formal co-management agreements. Provide sustainable livelihood support, capacity building and equitable benefit-sharing arrangements that incentivise long-term community stewardship of peat swamp forests.
	Promote paludiculture and sustainable peatland-compatible livelihoods	Support the transition of communities and smallholders on degraded peatlands (especially around forest reserves) toward paludiculture, including cultivation of species such as sago palm (*Metroxylon sagu*), *jelutong* (*Dyera polyphylla*), *gelam* (*Melaleuca* spp.), aquaculture and non-timber forest product harvesting, as economically viable alternatives to drainage -based land use that maintain hydrological function and community wellbeing.

Taken together, these recommendations constitute a coherent and actionable framework for strengthening the governance of peat swamp forests in Peninsular Malaysia. Their effective implementation requires sustained political commitment, enhanced institutional coordination and long-term financial investment at both federal and state levels. However, the ecological, economic and social benefits, including reduced flood risk, preserved carbon stocks, conserved biodiversity, and improved community livelihoods, are expected to substantially outweigh the costs of continued inaction.

CONCLUSION

Peninsular Malaysia's peat swamp forests, spanning Selangor, Pahang, Terengganu, Johor, and beyond, represent among the most carbon-dense terrestrial ecosystems in the region, storing carbon at densities far exceeding those of dryland forests. They also play a critical role in regulating freshwater hydrology across densely populated coastal lowlands, sustaining irreplaceable biodiversity and supporting communities that have long served as their most committed custodians. The scientific evidence is compelling. Peatlands must remain hydrologically intact to maintain their ecological function. Hydrological integrity must

therefore be restored and maintained at the landscape scale, while fire prevention must consistently take precedence over reactive suppression. Governance arrangements require stronger coordination across agencies, tenure systems and administrative levels. Communities must be formally recognised and adequately supported as frontline stewards with meaningful roles in monitoring, restoration, and management. Conservation investment must be sustained, strategic, and proportionate to the ecological and socioeconomic value of these ecosystems. Case studies from northern and southern Selangor, Southeastern Pahang, and Johor demonstrate that restoration is achievable, that community partnership delivers results and that integrated management frameworks can align ecological, economic and social objectives within a single landscape. Growing institutional commitments across all four landscapes signal a genuine readiness to shift from reactive crisis management toward proactive stewardship. What remains limiting is not the absence of knowledge, but rather the need for stronger coordination in governance, financing, and political prioritisation. By recognising peat swamp forests as irreplaceable natural infrastructures rather than marginal or degraded land and ensuring these landscapes remain wet, empowering local communities in stewardship roles, and making certain that policies are coherently implemented, Malaysia can safeguard these critical ecosystems as enduring ecological assets for future generations.

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APPENDIX

Annex 1. Case Studies: Peat Swamp Forest Management Across Peninsular Malaysia

The four case studies presented in this Annex span the length of Peninsular Malaysia, from the urban fringe of Greater Kuala Lumpur to the coastal plains of Pahang and the southern frontier of Johor. Each landscape reflects distinct ecological conditions, governance histories and human pressures, yet all share a common imperative: long term conservation of peat swamp forests demands integrated landscape-scale management, sustained financial and institutional support and genuine partnership with local and Indigenous communities.

Johor Peat Swamp Forests: Rediscovery and Restoration at the Southern Frontier

Johor's peat swamp forests as shown in Figure A1 represent one of the most recently documented and least systematically characterised peatland landscapes in Peninsular Malaysia. Through rapid field assessment and GIS mapping cross-referenced against state peatland distribution data and Permanent Reserved Forest boundaries, six peat swamp forest areas have been identified in Johor, comprising four Permanent Reserved Forests and two Class Two Protected Forests, namely Ayer Hitam Utara (2,804.47 ha), Ayer Hitam Utara Tambahan (358.85 ha), Gunung Arong (1,483.90 ha), Gunung Arong Tambahan (95.15 ha), Sedili Kecil (676.51 ha) and Pantai Timur (967.55 ha), with a combined peat swamp forest extent of approximately 6,386 hectares across the six areas (Johor State Forestry Department 2021).

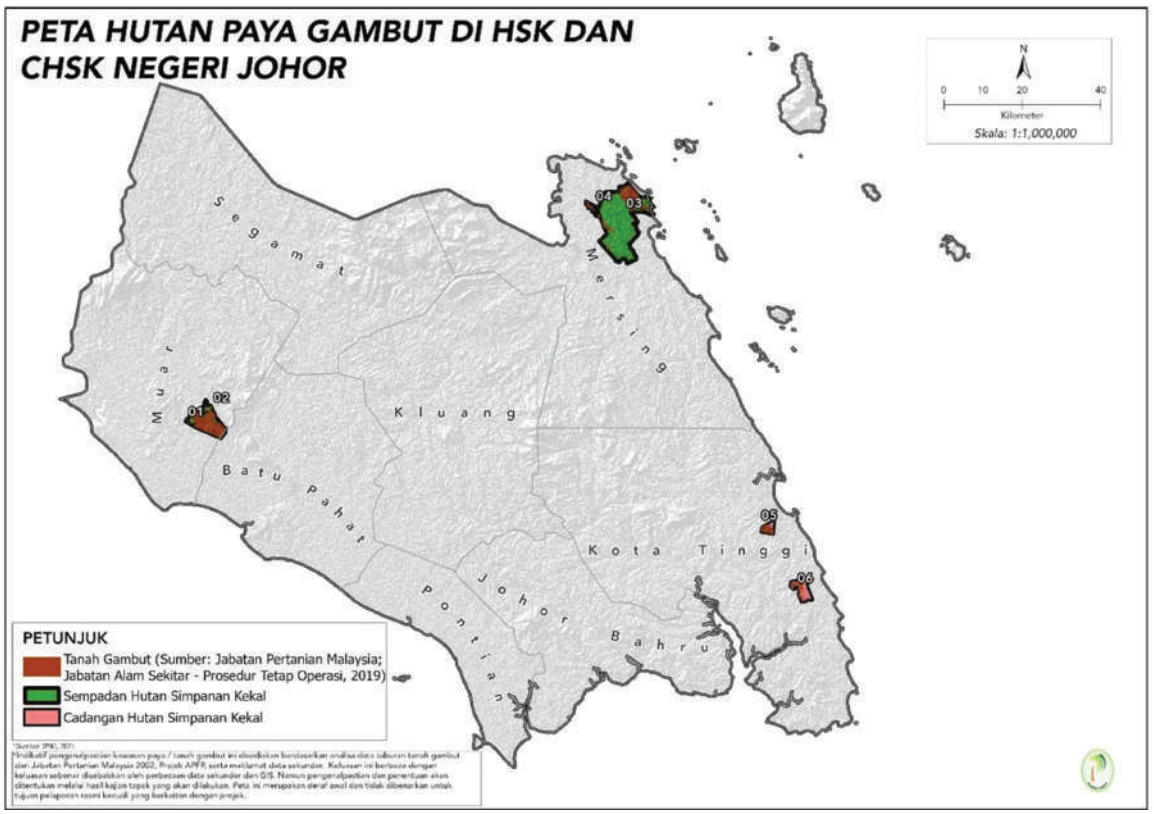

Figure A1. Distribution of peat swamp forests within gazetted and proposed Permanent Reserved Forests across Johor, showing six identified peat swamp forest areas across the Muar, Mersing and Kota Tinggi districts (Johor State Forestry Department 2021).

Field assessments confirmed significant variation in peat depth and forest condition across these sites. Ayer Hitam Utara contains peat ranging from 0.5 metres in degraded compartments to 8.16 metres in relatively intact interior areas, supporting species including *kempas* (*Koompassia malaccensis*), *meranti paya* (*Rubroshorea platycarpa*), *ramin melawis* (*Gonystylus bancanus*) and *mersawa paya* (*Anisoptera marginata*). Gunung Arong supports peat depths of up to 4.75 metres in areas identified as having high conservation potential, while Sedili Kecil and Pantai Timur, with depths of 2.73 to 3.20 metres, retain good forest structure despite localised fire damage and edge disturbance (Johor State Forestry Department 2021; GEC 2023–2025).

The condition of these forests ranges from well-stocked intact stands to heavily degraded areas with high fire risk, reflecting the consequences of drainage, encroachment and the absence of formal integrated landscape level management framework over time. The Johor State Peat Swamp Forest Management Plan 2021 to 2030, together with the seven-year conservation project at Gunung Arong Forest Reserve in Mersing Undertaken by GEC with support of TH Plantations Berhad, represents the most significant commitment to date to reverse degradation trends through integrated assessment, community engagement, hydrological restoration and biodiversity conservation interventions (Johor State Forestry Department 2021).

The Southeast Pahang Peatland Landscape: Scale, Fire, and Indigenous Communities

The Southeast Pahang Peat Swamp Forest (SEPPSF) as shown in Figure A2 is the largest remaining peatland complex in Peninsular Malaysia, encompassing a total gazetted area of 97,650.33 hectares within Permanent Reserved Forests, primarily distributed across the Pekan forest district (86,065 ha) and Rompin (11,585.33 ha) (modified from Pahang State Forestry Department, 2023). The landscape comprises the Pekan, Kedondong, Nenasi and Resak Forest Reserves, with additional areas gazetted since 2010 to strengthen landscape connectivity and hydrological integrity. It provides critical habitat for threatened species within the peat swamp ecosystem, including the sun bear (*Helarctos malayanus*) and Malayan tapir (*Tapirus indicus*), Hairy-nosed otter (*Lutra sumatrana*) and flat-headed cat (*Prionailurus planiceps*), alongside 38 freshwater fish species and 141 recorded tree species including *ramin melawis* (*Gonystylus bancanus*) and *meranti* (*Shorea* spp.) (Enggang Holdings Sdn. Bhd. 2025). The landscape further supports 26 Orang Asli villages/sub-villages from the Jakun sub-group who remain closely dependent on forest resources for sustenance and livelihood.

Despite its ecological significance, the SEPPSF faces severe and compounding pressures. Large-scale drainage of surrounding state land has fundamentally fragmented the natural hydrological system, lowering water tables across extensive peat areas and rendering them highly susceptible to recurrent fire. Suppression costs have consistently and substantially exceeded investments in prevention and hydrological restoration, reflecting an unsustainable pattern of reactive rather than proactive management (Smith *et al.* 2018; GEC 2023). In response, the Pahang State Forestry Department, in collaboration with other government technical departments, the Global Environment Centre and private sector partners, has initiated targeted interventions including peatland rewetting through canal blocking, community-based fire monitoring and active engagement of surrounding Orang Asli communities as frontline stewards. The fire prevention and conservation project at the Bukit Leelau Mini landscape in the western portion of the landscape has prevented peatland fires for seven years since March 2019, through effective cross-agency multiple-disciplinary partnership. GEC has been facilitated regular patrols by Orang Asli villagers to prevent fires and monitor water levels and encroachment. On the eastern side of SEPPSF, a similar project implemented since 2021, has made measurable progress in reducing fire incidence and restoring hydrological function as a foundation for longer-term landscape recovery (GEC and Yayasan Pahang Plantation Holdings 2025).

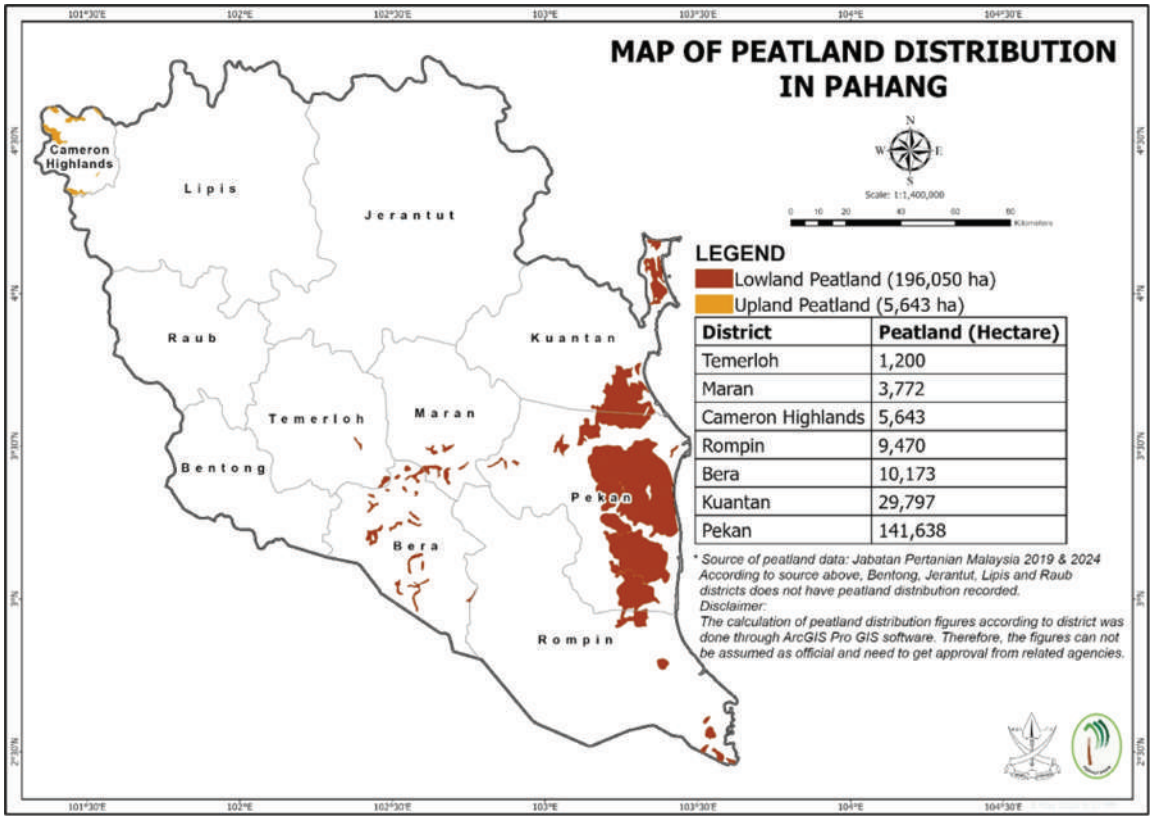

Figure A2. Distribution of peatland in Pahang.

North Selangor Peat Swamp Forest: Managing at Scale

The North Selangor Peat Swamp Forest (NSPSF) (Figure A3) covering 81,530 hectares across five Permanent Reserved Forests in Kuala Selangor, Sabak Bernam and Hulu Selangor, is the second largest contiguous peat swamp forest in Peninsular Malaysia. It harbours 107 tree species, 173 bird species, 46 mammal species and more than 120 fish species, alongside critically threatened flora including *ramin melawis* (*Gonystylus bancanus*, Critically Endangered), *meranti bakau* (*Rubroshorea uliginosa*, Endangered) and *meranti paya* (*Rubroshorea platycarpa*, Endangered). The NSPSF complex stores an estimated 143.63 million tonnes of carbon, with 137 million tonnes sequestered in below-ground peat soils and 6.63 million tonnes in above-ground biomass. This carbon stock is equivalent to 527 million tonnes of CO_2e, highlighting the significant climate mitigation potential that can be realised through the continued protection and conservation of this reserve. (Selangor State Forestry Department 2025a).

Despite its protected status, the NSPSF faces significant pressures from drainage, encroachment and recurring fires that have collectively undermined the ecological integrity of portions of the landscape. The Raja Musa Forest Reserve has nonetheless emerged as a restoration model, where a partnership between the State Forestry Department, GEC, local communities and the private sector since 2008. A combination of: canal blocking and rewetting degraded peatlands; community-based fire prevention; water level monitoring using piezometers; and active replanting of native species have successfully rehabilitated degraded areas and led to a 99% reduction in fires since 2014. These experiences have directly informed the preparation of the third Integrated Management Plan (2025 to 2034), which adopted six targeted management zones integrating climate mitigation, hydrological restoration, biodiversity conservation and sustained community engagement across the entire landscape (Selangor State Forestry Department 2025a).

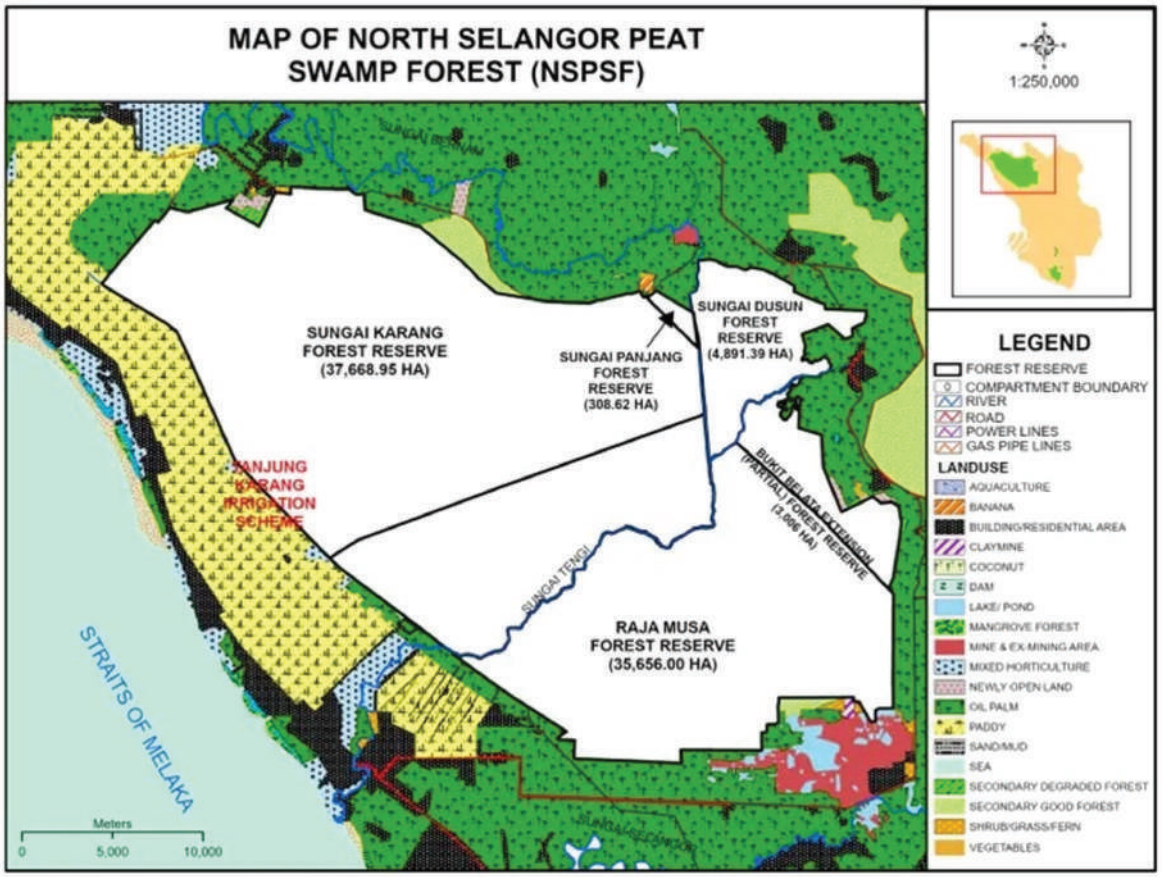

Figure A3. Map of the North Selangor Peat Swamp Forest (NSPSF) showing the five Permanent Reserved Forests comprising Raja Musa Forest Reserve (35,656 ha), Sungai Karang Forest Reserve (37,668.95 ha), Sungai Panjang Forest Reserve (308.62 ha), Sungai Dusun Forest Reserve (4,891.39 ha) and Bukit Belata Extension Forest Reserve (3,006 ha), together with the diversity of surrounding land uses including aquaculture, agriculture, plantations and residential areas (Selangor State Forestry Department, 2025a).

The South Selangor Peatland Landscape: Conservation at the Urban Fringe

The South Selangor Peat Swamp Forest (SSPSF) (Figure A4), covering 9,514.42 hectares across four Permanent Reserved Forests in Kuala Langat and Sepang districts, represents some of the last remaining peat swamp forest in southern Selangor. First gazetted in 1927, the landscape underwent significant transformation from 1974 onward due to degazettment of large portions of the landscape due to development pressures, leaving these remnant forests as critical refuges for threatened species including *meranti bunga* (*Rubroshorea teysmanniana*, Critically Endangered), *meranti bakau* (*Rubroshorea uliginosa*, Endangered) and *meranti paya* (*Rubroshorea platycarpa*, Endangered). The intact peat area of the SSPSF contains approximately 439,276 tonnes of biomass carbon stock, which is equivalent to 1.61 million tonnes of CO_2e. Based on the average peat depth measurements, the SSPSF is estimated to store about 9.29 million tonnes of below-ground carbon, corresponding to 34.09 million tonnes of CO_2e. (Selangor State Forestry Department 2025b).

A defining conservation challenge for this landscape has been the persistent threat of encroachment, drainage and recurring peat fires within and adjacent to the Kuala Langat South Forest Reserves. Given the SSPSF's location at the urban fringe of Greater Kuala Lumpur and its immediate proximity to Kuala Lumpur International Airport, peat fires in

this landscape carry consequences that extend well beyond ecological loss, directly affecting air quality, public health, airport operations and the livelihoods of surrounding communities. Active fire prevention through hydrological restoration, canal blocking and sustained water table management is therefore the single most critical management intervention required to safeguard what remains of this landscape. The local Temuan Orang Asli community, who have maintained a long presence within and around these forests, have demonstrated meaningful commitment to forest stewardship through active participation in replanting and monitoring efforts (Koshy 2023). Their continued involvement in fire prevention, early warning monitoring and rehabilitation activities represents an invaluable and underutilised resource in the long-term protection of the SSPSF. The IMP-SSPSF 2025-2034 formalises this integrated approach across four management zones, embedding fire prevention, nature-based hydrological restoration and sustained community engagement as the cornerstones of landscape management (Selangor State Forestry Department 2025b).

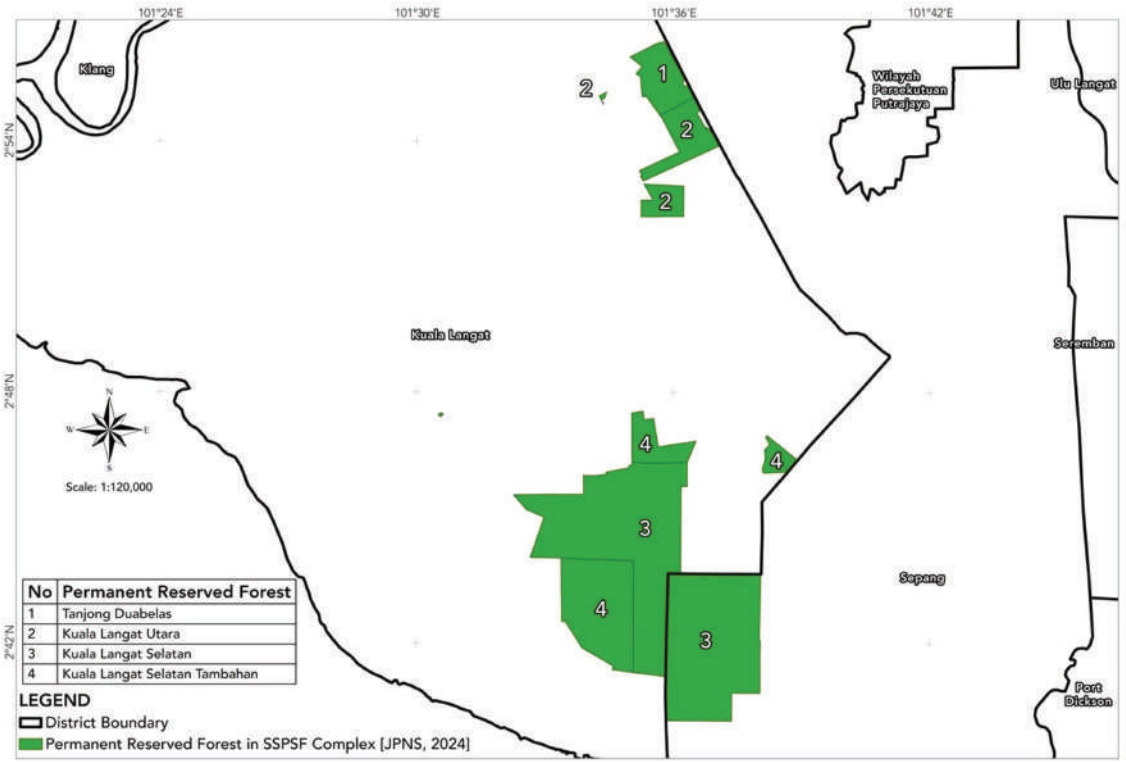

Figure A4. Gazetted Permanent Reserved Forests of the South Selangor Peat Swamp Forest (SSPSF) complex across the Kuala Langat and Sepang districts in the southern Selangor, covering a total area of 9,514.42 hectares across four forest reserves (Selangor State Forestry Department 2025b).