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COCONUT PLANTATION FIRES: A REVIEW OF DRIVERS, IMPACTS, AND MITIGATION STRATEGIES

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Abstract

Fires in coconut plantations, especially on tropical peatlands, cause serious environmental and economic problems. While most studies focus on oil palm, this literature review summarizes the causes, impacts, prevention methods, and restoration strategies specific to coconut plantations. The review shows that fires are mainly triggered by cheap land-clearing practices and the accumulation of dry wastes like husks and fronds, which become highly flammable during El Niño droughts and over-drainage. These fires cause direct palm mortality, reduce crop yields for up to three years, cause peat subsidence, and generate dangerous smoke haze that harms public health. To prevent these fires, strategies like proper water management, community involvement, and satellite or drone monitoring are essential. For post-fire recovery, maintaining the surviving coconut canopy and using coconut fiber as mulch offer cost-effective ways to restore soil and biodiversity. In conclusion, managing fires requires a combination of better waste management, water control, and active community participation.

Keywords: *Coconut plantations, Fire prevention, Post-fire restoration, Smoke haze*

INTRODUCTION

Global climate change is causing extreme weather events, such as droughts, to occur more frequently. These climatic conditions are considered a major cause of the increasing frequency and scale of damage caused by forest fires (Abatzoglou & Williams, 2016; Bowman et al., 2020; IPCC, 2021). Globally, the frequency of large fires is increasing, and the forest fire season is becoming longer, causing severe ecological and economic losses. In the era of the climate crisis, it is particularly concerning that forest fires release large amounts of carbon dioxide into the atmosphere in a short period of time. This released carbon dioxide exacerbates climate change (Lee et al., 2023).

The amount of fire-prone land is predicted to increase globally as a result of climate change (Abram et al., 2021; Anderegg et al., 2022; Canadell et al., 2021; Jones et al., 2020). However, beyond the impact of climate change on forest fires, land management practices (including forests and plantations) can also influence fire risk and impact important aspects of the fire regime, such as fire severity (D. Lindenmayer et al., 2021; Wilson et al., 2022; Zylstra et al., 2022) and fire extent (Andela et al., 2017; Levine et al., 2022). However, the risk of fires in coconut plantations is driven by the awareness of communities in each village that the negative impacts of fires will be reduced. Fires generally do not occur naturally and must be ignited by humans, either intentionally or accidentally. One study found that communities are aware of the causes of forest and land fires, and 82% blamed human carelessness for burning their land for agriculture (Muslim et al., 2017).

Several integrated management strategies have been proposed to address the threat of fire, including law enforcement, landscape planning that disrupts land continuity, and local community involvement (Jimu & Nyakudya, 2018; D. B. Lindenmayer et al., 2023). Furthermore, the use of modern technologies such as satellite sensors and autonomous vehicles is recommended for more efficient fire detection and suppression (Andrew, 2022). Most previous studies have focused on palm oil or industrial plantations, leaving a gap in information regarding the characteristics of fire management in coconut trees (Varkkey, 2011). To bridge this knowledge gap, a comprehensive literature review is needed to synthesize diverse perspectives and scattered scientific findings. This review article aims to summarize the causes, impacts, and prevention methods of fires based on existing articles.

DRIVERS OF FIRE INCIDENTS IN COCONUT PLANTATIONS

Land fires in coconut plantations, particularly those located within peatland ecosystems, constitute a complex issue involving the intricate interplay among human activities, environmental conditions, and land governance systems. Anthropogenic activities serve as the primary trigger, with land burning being regarded as the most economically rational method (Tan et al., 2009). The cost of clearing land using fire ranges from merely USD 5 per hectare, which is significantly more cost-effective than mechanical methods that can reach up to USD 250 per hectare (Tan et al., 2009; Varkkey, 2015). Beyond cost efficiency, a strong belief persists among farmers that the resulting ash can enhance soil nutrients and neutralize the high acidity levels characteristic of peat soils (Fawzi et al., 2021). This practice is also functionally employed to manage plantation waste, such as husks and dry fronds, to prevent pest infestations, despite the inherent risk of triggering uncontrolled wildfires. Furthermore, human negligence, such as the disposal of cigarette butts on dry land, remains a persistent source of fire ignition.

Climate variability, particularly the El Niño phenomenon, acts as a catalyst that significantly exacerbates fire risks (Warren et al., 2017). During prolonged drought periods induced by El Niño, precipitation declines drastically, causing groundwater tables to drop and rendering the peat layer extremely dry (Prayoto et al., 2017). Under these conditions, peatlands transform into a highly combustible tinderbox, prone to burning not only on the surface but also beneath it (ground fires). These subsurface fires are exceptionally difficult to suppress and can smolder for weeks, releasing massive amounts of carbon emissions into the atmosphere. This situation is further compounded by failures in plantation water and drainage management systems. Conventionally, cultivating coconut palms on peatlands requires drainage to lower the water table for optimal crop growth. However, the construction of deep canals often leads to over-drainage, which triggers irreversible drying of the peat (Fawzi et al., 2021). Interestingly, studies demonstrate that corporate-managed plantations exhibit a higher fire vulnerability (8.4%) compared to independent smallholder lands (1.8%) (Prayoto et al., 2017). This discrepancy arises because local smallholders tend to utilize shallow canal systems and leverage natural tidal movements to maintain soil moisture, whereas corporations frequently neglect hydrological balance in favor of rapid expansion.

In addition to external factors such as climate and water management, the intrinsic characteristics of coconut palms and their production patterns contribute significantly to the fuel load within plantation areas. As a monoculture crop, coconut palms generate substantial quantities of organic waste which, if improperly managed, become highly flammable materials. The biological traits and canopy structure of coconut palms present distinct challenges in land management. Monoculture coconut plantations often leave extensive open spaces (approximately 84.6% of the land is unoccupied by tree trunks), allowing the proliferation of understory vegetation, such as shrubs and grasses, between the trees (Advisory Circular, 2018; Senarathne S.H.S, 2019). This understory vegetation, combined with natural coconut waste such as dry fronds and husks, creates a continuous accumulation of biomass (Fawzi et al., 2021). Coconut husks, in particular, possess dry and lightweight physical properties, making them highly effective fuels that facilitate the rapid spread of surface fires (Fawzi et al., 2021; Varkkey, 2015).

The dilemma of plantation waste management frequently compels farmers to utilize fire as a practical solution; leaving accumulated coconut husks unmanaged within plantation areas is known to provide breeding grounds for various crop-damaging pests (Fawzi et al., 2021). Consequently, farmers often engage in controlled burning to dispose of these husk and dry frond wastes. Although intended for small-scale clearance, this practice carries a high risk of escaped fires triggering larger landscape conflagrations, particularly when airborne sparks land on dry peat or surrounding understory vegetation.

THE IMPACTS OF PLANTATION FIRES

Fire incidents in coconut plantations, particularly those situated on tropical peatlands, result in a complex interplay between immediate physical damage, long-term biological stress, and severe socio-economic disruptions. The direct impact of fire on coconut plantations involves the physical destruction of plantation assets and the mortality of coconut palms (Winarno et al., 2020). Unlike seasonal crops, coconut palms are perennial trees, meaning that weather anomalies and fire-induced stress exert long-term adverse effects (Singh et al., 2013). In regions such as Riau, Indonesia, where coconut plantations are frequently established on peatlands, fires act as a primary catalyst for peatland subsidence (the lowering of the ground surface elevation) (Saputra, 2019). Fires accelerate the oxidation of organic matter and degrade the structural integrity of the soil (Evans et al., 2019; Kieft et al., 2016). This land subsidence causes specific biological failures in coconut palms, manifested as tilting, sinking, or mortality, as their root systems are disrupted by shifting ground levels and increased flooding during subsequent rainy seasons. On the other hand, data analysis from regional studies reveals a stark contrast in fire vulnerability based on the scale of land management. This discrepancy is largely driven by drainage techniques; industrial plantations frequently utilize deep canals that over-drain the peat, thereby rendering it highly combustible. Conversely, smallholders typically employ shallow canals and leverage natural tidal movements to maintain soil moisture, which inherently prevents the peat from reaching the critical dryness thresholds required for ignition (Prayoto et al., 2017). Socio-economic impacts are most pronounced in districts such as Indragiri Hilir, where coconut is the predominant plantation crop and the primary source of livelihood for millions of people (Saputra, 2019). As these primary livelihoods are severely diminished or entirely lost, widespread economic hardship ensues. This destruction frequently forces shifts in community dynamics, leading to reduced household incomes, the depletion of natural resources, and increased migration as laborers seek employment in other regions or sectors (Chokkalingam et al., 2007). In addition to accidental fires, the literature highlights that fire is occasionally utilized as a deliberate tool in land tenure conflicts. In some instances, local communities repeatedly set fire to corporate plantation areas as a form of protest or to assert territorial claims in zones where land ownership is disputed (Chokkalingam et al., 2007). This social dimension introduces further complexity to fire mitigation efforts, demonstrating that fires are not merely biophysical events but also symptoms of underlying institutional and land tenure disputes.

Fires generate substantial particulate emissions and thick, dense smoke (haze), posing a grave concern for public health (Noojipady et al., 2017). Exposure to this smoke directly causes respiratory illnesses among populations residing near the fire sites as well as those in downwind areas affected by transboundary haze (Wicke et al., 2011). Historically, major fire events have caused widespread health impacts. For example, during the catastrophic 1997–1998 fire event in Riau, it was estimated that approximately 10 percent of the total population experienced fire-related health complications (Saputra, 2019). The severe 2015 fires were similarly documented to cause serious health issues for the public (Winarno et al., 2020)(Syaufina, 2018). Globally, smoke from landscape fires is associated with a significant estimated mortality rate. This indicates that the impacts of smoke are not merely temporary nuisances but can be fatal. Greenhouse gas and particulate emissions from peat combustion produce transboundary haze pollution, which compromises public health in the population centers of neighboring countries, such as Singapore. Due to the profound social disruptions caused by the heightened health risks of such air pollution, local governments are frequently forced to implement emergency policies, such as closing schools and offices, to protect the public from hazardous smoke exposure (Saputra, 2019). On the other hand, land management systems such as agroforestry can help foster improved microclimatic conditions (such as the regulation of ambient temperature and humidity) that support the healthier growth of humans, plants, and animals compared to monoculture systems, which are more vulnerable to extreme temperatures (Dissanayaka et al., 2023).

FIRE PREVENTION STRATEGIES

One method that has proven effective on peatlands is the application of the Water Management Trinity (WMT) system, which uses a network of canals and dams to regulate the groundwater level so that it remains wet even during the dry season, thereby reducing the land's vulnerability to fire (Fawzi et al., 2021). In plantation forest areas, managers carry out routine fuel management through clearing bushes, pruning dead branches, and thinning trees to reduce the accumulation of flammable dry biomass (D. B. Lindenmayer et al., 2023). Apart from that, the creation of physical fire breaks and the use of fire-resistant plants as barriers between plantation blocks are implemented to cut fire connectivity so that it does not spread if a fire occurs (Saharjo, 1997).

Active involvement and empowerment of communities around the land is also an important factor in sustainable fire prevention. The transformation of community behavior from slash-and-burn practices to no-burn farming is encouraged through intensive education programs and outreach regarding the dangers of fire and the legal sanctions that accompany it (Andrew, 2022). Communities are encouraged to form independent fire patrol groups and take collective responsibility in extinguishing small fires before they grow (Fawzi et al., 2021).. To strengthen citizens' commitment, companies or the government can provide incentives through partnership or profit sharing schemes (such as out-grower schemes), which create a sense of ownership so that people are motivated to protect forest assets from the threat of fire or sabotage due to land conflicts (Jimu & Nyakudya, 2018). On the other hand, the government must ensure legal certainty regarding land ownership to avoid deliberate burning (arson) which is often a weapon in agrarian conflicts (Applegate et al., 2001). Strict law enforcement, which involves coordination between security forces and related agencies, provides a significant deterrent effect for individuals and corporations who ignore fire prevention regulations (Fawzi et al., 2021).

FIRE MONITORING AND DETECTION TECHNOLOGIES

Fire spot monitoring technology includes the use of satellite imagery such as MODIS (on the Terra and Aqua satellites), NOAA-AVHRR, and ATSR which are capable of detecting hotspots and mapping the area of burned areas daily from space (Fawzi et al., 2021). Apart from satellites, a fleet of drones (UAVs) equipped with infrared sensors are used to quickly detect fire ignitions in plantation locations, even in night conditions or bad weather (D. B. Lindenmayer et al., 2023). The use of fire monitoring towers combined with a network of ground-based sensor cameras also provides 24-hour visual surveillance capabilities for early detection in plantation forest areas (D. B. Lindenmayer et al., 2023; Saharjo, 1997). As a complement at the site level, a reporting system based on village community patrols and the company's internal fire team uses communication tools and participatory mapping to monitor the emergence of fire directly to ensure a quick response before the fire spreads widely (Fawzi et al., 2021).

POST-FIRE LAND RESTORATION AND RECOVERY

Land recovery after a fire is an important stage after the fire is completely extinguished and the area is declared safe. This activity not only aims to clean up the remnants of the fire, but also restore soil function, accelerate vegetation regeneration, reduce the risk of erosion, and prevent repeated fires. On plantation land, including coconut plantations, restoration needs to be carried out gradually because fires can damage crops, degrade soil quality, remove organic matter, and disrupt the balance of ecosystems(Menéndez-Miguélez et al., 2025). The first step of recovery is the selective cleaning of fire residues. Burnt trees, branches, twigs, fronds, or wood should be removed when obstructing access, potentially collapsing, or endangering workers(Malvar et al., 2017). However, cleaning should not be done excessively because it can make the soil more exposed and susceptible to erosion. Some organic materials that are still safe can be used as natural mulch to maintain moisture, reduce water runoff, and resist erosion, especially on sloping land(Malvar et al., 2017).

The next strategy is natural regeneration and natural regeneration assistance. Natural regeneration can take place if there is still a source of seeds, plant roots that are able to grow back, and soil conditions have not been severely damaged(Scheper et al., 2021). However, in severely burned tropical lands, restoration often requires interventions through weed control, erosion control, natural shoot protection, and rewetting of dried peatlands(Scheper et al., 2021). Thus, recovery does not always have to be through total planting, but can take advantage of the ecosystem's natural ability to recover. In addition, replanting and vegetation enrichment are important in areas that have suffered heavy damage. Planting native tree seedlings or direct seeding can accelerate the formation of vegetation cover(Scheper et al., 2021). In the context of a coconut plantation, the surviving coconut plant does not always have to be cut down. The remaining coconut canopy can create a more shaded environment, retain micromoisture, and accelerate natural succession compared to full land clearing(Scheper et al., 2021). Therefore, the decision to cut down or maintain the crop needs to consider the extent of damage, safety, and ecological benefits.

The use of mulch and organic matter also plays an important role in improving the soil after the fire. Mulching such as coconut fiber, wood chips, straw, or local organic materials can reduce erosion, improve water retention, maintain moisture, and improve soil quality(Barreiro et al., 2016; Dorosh et al., 2025; Wittenberg et al., 2020). In coconut plantations, coconut fiber is very potential because it is easy to obtain, has relatively slow decomposition, and is suitable for long-term soil stabilization(Barreiro et al., 2016). The use of local organic materials is also more efficient because it reduces costs while utilizing plantation waste. Post-fire management also needs to be focused on preventing erosion and further disturbances. Erosion barriers such as logs, twigs, simple gulunds, or coconut fibers can slow the flow of surface water and reduce the loss of the topsoil layer(Dorosh et al., 2025; Wittenberg et al., 2020). In addition, the prevention of the re-entry of fires into the recovery area is essential to support vegetation regeneration. This effort needs to be supported through supervision, patrols, public education, and regulation of fire use activities around the land(Papaioannou et al., 2023; Scheper et al., 2021).

The success of restoration can be seen from increasing vegetation cover, improving soil quality, and returning biodiversity. Studies on post-fire lands of coconut plantations show that bird diversity can increase within 2 to 4 years after a fire, including the emergence of several protected bird species(Putri & Santosa, 2020). This shows that post-fire land still has the ability to recover if it is managed properly and protected from repeated fires. From the soil aspect, the application of organic matter can increase the content of organic matter, maintain moisture, improve water retention, and reduce erosion(Barreiro et al., 2016; Dorosh et al., 2025; Wittenberg et al., 2020). Improving soil quality is critical because successful replanting depends on the availability of water, nutrients, and appropriate growing environmental conditions(Purnomo et al., 2019). Without adequate soil recovery, seedlings are at high risk of mortality, especially in the dry season.

Recovery strategies also need to consider cost efficiency. In coconut plantations, the approach that maintains the coconut canopy is considered more economical than the cut-off method because it does not require complete cleaning, reduces recovery inputs, and still provides natural shade(von Brandis, 2012). This approach also supports ecosystem restoration because the remaining vegetation structures still serve as habitats, sources of organic matter, and soil protectors. The main challenge in land recovery is recurrent fires, as young vegetation and soil organic layers are not strong enough to withstand the next fire disturbance(Scheper et al., 2021). In addition, there is a potential conflict between the goal of ecosystem restoration and the interests of commercial production, such as coconut or oil palm(Purnomo et al., 2019). Therefore, recovery needs to combine ecological, economic, and social aspects in a balanced manner. Based on this description, post-fire land restoration of coconut plantations needs to be carried out through an integrated approach, including selective cleaning, natural regeneration, natural regeneration assistance, replanting, vegetation enrichment, mulch use, erosion control, and prevention of recurrent fires. An approach that maintains a coconut canopy can be a more efficient option as it helps accelerate ecosystem recovery at a lower cost. The success of restoration is highly dependent on the level of land damage, soil conditions, availability of organic materials, availability of communities, and consistency of long-term management.

CONCLUSION

In conclusion, fires in coconut plantations are a major problem caused by a combination of human activities and dry weather. Burning land remains a cheap option for farmers to clear land and manage waste, but it creates a high risk of uncontrolled fires, especially during El Niño droughts when peatlands and dry coconut husks become highly flammable. The impacts are severe, ranging from immediate damage to coconut palms and long-term yield losses to land subsidence and public health crises from smoke haze. To address this issue, the focus must shift from fire suppression to fire prevention. This can be achieved through proper water management to keep peatlands wet, community-based fire patrols, and early detection using technologies like satellites and drones. After a fire occurs, land restoration should focus on simple and cost-effective methods. Keeping the remaining coconut canopy to maintain soil moisture and using coconut fiber as mulch to prevent erosion are effective ways to accelerate ecosystem recovery. Cooperation between farmers, companies, and the government is the key to creating fire-resilient coconut plantations.

REFERENCES

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, *113*(42), 11770–11775. https://doi.org/10.1073/pnas.1607171113

Abram, N. J., Henley, B. J., Sen Gupta, A., Lippmann, T. J. R., Clarke, H., Dowdy, A. J., Sharples, J. J., Nolan, R. H., Zhang, T., Wooster, M. J., Wurtzel, J. B., Meissner, K. J., Pitman, A. J., Ukkola, A. M., Murphy, B. P., Tapper, N. J., & Boer, M. M. (2021). Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth & Environment*, *2*(1), 8. https://doi.org/10.1038/s43247-020-00065-8

Advisory Circular. (2018). *Intercropping in coconut land (Lunuvila, Sri Lanka: Coconut Research Institute of Sri Lanka)*. https://cri.gov.lk/wp-content/ uploads/2021/10/c1.pdf.

Andela, N., Morton, D. C., Giglio, L., Chen, Y., van der Werf, G. R., Kasibhatla, P. S., DeFries, R. S., Collatz, G. J., Hantson, S., Kloster, S., Bachelet, D., Forrest, M., Lasslop, G., Li, F., Mangeon, S., Melton, J. R., Yue, C., & Randerson, J. T. (2017). A human-driven decline in global burned area. *Science*, *356*(6345), 1356–1362. https://doi.org/10.1126/science.aal4108

Anderegg, W. R. L., Chegwidden, O. S., Badgley, G., Trugman, A. T., Cullenward, D., Abatzoglou, J. T., Hicke, J. A., Freeman, J., & Hamman, J. J. (2022). Future climate risks from stress, insects and fire across US forests. *Ecology Letters*, *25*(6), 1510–1520. https://doi.org/https://doi.org/10.1111/ele.14018

Andrew, S. M. (2022). Drivers, trends and management of forest plantation fires in Tanzania. *Trees, Forests and People*, *10*(November). https://doi.org/10.1016/j.tfp.2022.100355

Applegate, G., Chokkalingam, U., & Suyanto. (2001). *The Underlying Causes and Impacts of Fires in South-east Asia*.

Barreiro, A., Bååth, E., & Díaz-Raviña, M. (2016). Bacterial and fungal growth in burnt acid soils amended with different high C/N mulch materials. *Soil Biology and Biochemistry*, *97*, 102–111. https://doi.org/10.1016/j.soilbio.2016.03.009

Bowman, D. M. J. S., Kolden, C. A., Abatzoglou, J. T., Johnston, F. H., van der Werf, G. R., & Flannigan, M.

(2020). Vegetation fires in the Anthropocene. *Nature Reviews Earth & Environment*, *1*(10), 500–515. https://doi.org/10.1038/s43017-020-0085-3

Canadell, J. G., Meyer, C. P. (Mick), Cook, G. D., Dowdy, A., Briggs, P. R., Knauer, J., Pepler, A., & Haverd, V. (2021). Multi-decadal increase of forest burned area in Australia is linked to climate change. *Nature Communications*, *12*(1), 6921. https://doi.org/10.1038/s41467-021-27225-4

Chokkalingam, U., Suyanto, Permana, R. P., Kurniawan, I., Mannes, J., Darmawan, A., Khususyiah, N., & Susanto, R. H. (2007). Community fire use, resource change, and livelihood impacts: The downward spiral in the wetlands of southern Sumatra. *Mitigation and Adaptation Strategies for Global Change*, *12*(1), 75–100. https://doi.org/10.1007/s11027-006-9038-5

Dissanayaka, D. M. N. S., Dissanayake, D. K. R. P. L., Udumann, S. S., Nuwarapaksha, T. D., & Atapattu, A. J. (2023). Agroforestry—a key tool in the climate-smart agriculture context: a review on coconut cultivation in Sri Lanka. *Frontiers in Agronomy*, *5*(May), 1–12. https://doi.org/10.3389/fagro.2023.1162750

Dorosh, O., Delerue-Matos, C., Castro, P., & Moreira, M. M. (2025). Moderate to high-severity wildfires: Main restoration strategies applied in Mediterranean ecosystems. *Journal of Environmental Management*, *380*. https://doi.org/10.1016/j.jenvman.2025.125149

Evans, C. D., Williamson, J. M., Kacaribu, F., Irawan, D., Suardiwerianto, Y., Hidayat, M. F., Laurén, A., & Page, S. E. (2019). Rates and spatial variability of peat subsidence in Acacia plantation and forest landscapes in Sumatra, Indonesia. *Geoderma*, *338*, 410–421. https://doi.org/10.1016/j.geoderma.2018.12.028

Fawzi, N. I., Qurani, I. Z., & Darajat, R. (2021). Alleviating peatland fire risk using water management trinity and community involvement. *IOP Conference Series: Earth and Environmental Science*, *914*(1). https://doi.org/10.1088/1755-1315/914/1/012037

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

Jimu, L., & Nyakudya, I. W. (2018). Fires in exotic forest plantations of Zimbabwe: Causes and management strategies. *World Development Perspectives*, *9*(August 2017), 56–58. https://doi.org/10.1016/j.wdp.2018.04.006

Jones, M. W., Smith, A., Betts, R., Canadell, J. G., Prentice, I. C., & Le Quéré, C. (2020). *Climate Change Increases the Risk of Wildfires*. Tyndall Centre for Climate Change Research.

Kieft, J., Smith, T., Someshwar, S., & Boer, R. (2016). *Towards Anticipatory Management of Peat Fires to Enhance Local Resilience and Reduce Natural Capital Depletion* (pp. 361–377). https://doi.org/10.1007/978-3-319-43633-3_16

Lee, C. ., Kang, W. ., Kwon, C. ., Kim, S. ., Kim, E. ., No, N. ., Ryu, J. ., Park, B. ., & Park, J. . (2023). *Scientific Understanding of Forest Fire Management*. Jieul.

Levine, J. I., Collins, B. M., Steel, Z. L., de Valpine, P., & Stephens, S. L. (2022). Higher incidence of high-severity fire in and near industrially managed forests. *Frontiers in Ecology and the Environment*, *20*(7), 397–404. https://doi.org/https://doi.org/10.1002/fee.2499

Lindenmayer, D. B., Yebra, M., & Cary, G. J. (2023). Better managing fire in flammable tree plantations. *Forest Ecology and Management*, *528*(November 2022). https://doi.org/10.1016/j.foreco.2022.120641

Lindenmayer, D., Zylstra, P., Taylor, C., Kooyman, R., Ward, M., & Watson, J. E. . (2021). Logging effects outweighed fire weather effects to promote crown fire in the 2019–20 Australian forest fires. *Figshare*.

Malvar, M. C. S., C., F., Prats, S. A., Vieira, D. C. S., Coelho, C. O. A., & Keizer, J. J. (2017). Short-term effects of post-fire salvage logging on runoff and soil erosion. *Forest Ecology and Management*. https://doi.org/10.1016/j.foreco.2017.06.031

Menéndez-Miguélez, M., Cañellas, I., Erdozain, M., de-Miguel, S., & Alberdi, I. (2025). Post-fire treatments in Mediterranean forests: a review for enhancing restoration strategies. *Fire Ecology*, *21*(1). https://doi.org/10.1186/s42408-025-00430-y

Muslim, T. W., Yoza, D., & Oktorini, Y. (2017). Identifikasi Faktor-faktor Penyebab dan Pencegahan Kebakaran Hutan dan Lahan Gambut di Kecamatan Kempas Kabupaten Indragiri Hilir. *Jurnal Online Mahasiswa Fakultas Pertanian Universitas Riau*, *4*(2), 1–15.

Noojipady, P., Morton, D. C., Schroeder, W., Carlson, K. M., Huang, C., Gibbs, H. K., Burns, D., Walker, N. F., & Prince, S. D. (2017). Managing fire risk during drought: The influence of certification and El Ninõ on fire-driven forest conversion for oil palm in Southeast Asia. *Earth System Dynamics*, *8*(3), 749–771. https://doi.org/10.5194/esd-8-749-2017

Papaioannou, G., Alamanos, A., & Maris, F. (2023). Evaluating Post-Fire Erosion and Flood Protection Techniques:

A Narrative Review of Applications. *GeoHazards*, *4*(4), 380–405. https://doi.org/10.3390/geohazards4040022

Prayoto, , Ishihara, M. I., Firdaus, R., & Nakagoshi, N. (2017). Peatland Fires in Riau, Indonesia, in Relation to Land Cover Type, Land Management, Landholder, and Spatial Management. *Journal of Environmental Protection*, *08*(11), 1312–1332. https://doi.org/10.4236/jep.2017.811081

Purnomo, E. P., Ramdani, R., Tomaro, Q. P. V, & Samidjo, G. S. (2019). Land ownership transformation before and after forest fires in Indonesian palm oil plantation areas. *Journal of Land Use Science*, *14*(1), 37–51. https://doi.org/10.1080/1747423X.2019.1614686

Putri, M. M., & Santosa, Y. (2020). Estimation of bird species diversity recovery on post-burnt land in PT Waimusi Agroindah, South Sumatera. *IOP Conference Series: Earth and Environmental Science*, *504*(1). https://doi.org/10.1088/1755-1315/504/1/012006

Saharjo, B. H. (1997). Fire protection and industrial plantation management in the Tropics. *Commonwealth Forestry Review*, *76*(3), 203–205.

Saputra, E. (2019). Beyond fires and deforestation: Tackling land subsidence in peatland areas, A case study from Riau, Indonesia. *Land*, *8*(5), 11–13. https://doi.org/10.3390/land8050076

Scheper, A. C., Verweij, P. A., & van Kuijk, M. (2021). Post-fire forest restoration in the humid tropics: A synthesis of available strategies and knowledge gaps for effective restoration. *Science of the Total Environment*, *771*, 144647. https://doi.org/10.1016/j.scitotenv.2020.144647

Senarathne S.H.S. (2019). Evaluation of Coconut Based Anacardium occidentale Agroforestry System to Improve the Soil Properties of Coconut Growing Lands in Wet, Intermediate and Dry Zone of Sri Lanka. *CORD*, *35*(01), 50. https://doi.org/10.37833/cord.v35i01.5

Singh, H. C. P., Shivashankara, K. S., & Rao, N. K. S. (2013). Climate-resilient horticulture: Adaptation and mitigation strategies. *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*, 1–302. https://doi.org/10.1007/978-81-322-0974-4

Syaufina, L. (2018). Forest and Land Fires in Indonesia: Assessment and Mitigation. In *Integrating Disaster Science and Management* (pp. 109–121). Elsevier. https://doi.org/10.1016/B978-0-12-812056-9.00008-7

Tan, K. T., Lee, K. T., Mohamed, A. R., & Bhatia, S. (2009). Palm oil: Addressing issues and towards sustainable development. *Renewable and Sustainable Energy Reviews*, *13*(2), 420–427. https://doi.org/10.1016/j.rser.2007.10.001

Varkkey, H. (2011). Plantation Land Management, Fires and Haze in Southeast Asia. *Malaysian Journal of Environmental Management*, *12*(2), 33–41.

Varkkey, H. (2015). *Plantation land management, fires and haze in southeast Asia*. *2011*.

von Brandis, R. G. (2012). Rehabilitation of abandoned coconut plantations at D'Arros Island, Republic of Seychelles. *Ocean and Coastal Management*, *69*, 340–346. https://doi.org/10.1016/j.ocecoaman.2012.09.003

Warren, M., Hergoualc'h, K., Kauffman, J. B., Murdiyarso, D., & Kolka, R. (2017). An appraisal of Indonesia's immense peat carbon stock using national peatland maps: uncertainties and potential losses from conversion. *Carbon Balance and Management*, *12*(1), 12. https://doi.org/10.1186/s13021-017-0080-2

Wicke, B., Sikkema, R., Dornburg, V., & Faaij, A. (2011). Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. *Land Use Policy*, *28*(1), 193–206. https://doi.org/10.1016/j.landusepol.2010.06.001

Wilson, N., Bradstock, R., & Bedward, M. (2022). Disturbance causes variation in sub-canopy fire weather conditions. *Agricultural and Forest Meteorology*, *323*, 109077. https://doi.org/https://doi.org/10.1016/j.agrformet.2022.109077

Winarno, B., Rohadi, D., Herawati, T., Rahmat, M., & Suwarno, E. (2020). Out of fire disaster: Dynamics of livelihood strategies of rural community on peatland use and management. *IOP Conference Series: Earth and Environmental Science*, *487*(1). https://doi.org/10.1088/1755-1315/487/1/012008

Wittenberg, L., van der Wal, H., Keesstra, S., & Tessler, N. (2020). Post-fire management treatment effects on soil properties and burned area restoration in a wildland-urban interface, Haifa Fire case study. *Science of the Total Environment*, *716*. https://doi.org/10.1016/j.scitotenv.2019.135190

Zylstra, P. J., Bradshaw, S. D., & Lindenmayer, D. B. (2022). Self-thinning forest understoreys reduce wildfire risk, even in a warming climate. *Environmental Research Letters*, *17*(4), 44022. https://doi.org/10.1088/1748-9326/ac5c10