Peatland Brief

Can Peatland Landscapes in Indonesia be Drained Sustainably? An Assessment of the *'eko-hidro'* Water Management Approach

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Preface

A large proportion of the peat swamp forest in Southeast Asia has been deforested and converted to drained land-uses, particularly oil palm and Acacia pulpwood plantations. This has caused the loss of biodiversity, huge greenhouse gas emissions, and the repeated occurrence of large scale peatland fires. The haze associated with these fires has had serious impacts on various economic sectors and public health. An effect less well known in Southeast Asia is that peatland oxidation inevitably causes the peatland to subside (i.e. peat soil is lost and the land surface consequently goes down), a process that continues for as long as the peat soil is drained. In most of the lowland peatlands the base of the peat lies at or near mean sea or river level. Continued subsidence will therefore eventually result in frequent and prolonged flooding of such drained peatlands. This process threatens to gradually change entire peatland dominated lowlands in large parts of Southeast Asia from economically productive landscapes into socio-economic disaster areas.

This long-term risk has generally not been taken into account in land-use planning and policy. One reason behind this is the persistent notion that peatland drainage may be implemented sustainably. In this regard, peatland policies in Indonesia have been strongly influenced by the so-called "eko-hidro" approach, a peatland management model developed by Asia Pacific Resources International Limited (APRIL), a large pulp-for-paper company with major assets on Indonesian peatlands. The model is claimed to provide a sustainable form of drainage-based peatland management. However, this claim is contradicted by the results of an increasing number of scientific publications from around the world.

The government of Indonesia has responded to peatland issues by endorsing new laws (e.g. PP71) and in 2016 the establishment of the national peatland restoration agency (Badan Restorasi Gambut; BRG). The BRG has a mandate to strengthen policies, map and prioritize peatland for restoration, execute, monitor and socialize peatland restoration and impose adjusted management on burned peatland in order to prevent peat fires. The ambition of the Indonesian government to restore 2 million hectares by 2020 signifies a radical change with the continuous expansion of peatland drainage in the past, and if realized, would constitute the largest peatland restoration programme in the world. However, the key issue of subsidence remains unaddressed by the current regulatory framework for existing drainage based plantations on peat. Effectively addressing this will require a paradigm shift in peatland utilization and management, involving a carefully planned phasing out of drained land-use on peat and the introduction of alternative economic uses that require no drainage. Peat swamp forests in Southeast Asia harbour many plant and tree species that require no drainage and have a high economic potential. Development of these will need substantial investment in research, pilot projects and upscaling.

Wetlands International and Tropenbos International developed this policy brief to call attention to this neglected issue, and to encourage further review of policies and land-use practices on peatlands in order to safeguard their long-term sustainable economic utilization. In addition, we believe that the currently remaining natural peat swamp forests should be protected and restored as a high priority, in view of the tremendous biodiversity of these areas and their disproportionately important function as carbon stores. This policy brief aims to contribute to the discussion in government, industry and civil society on how to scale-up and speed-up the process toward sustainably managed peatlands.

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Summary

The Government of Indonesia is taking important steps to address the extensive drainage of peatlands that has been a key factor in the expansion of forest and peatland fires and related haze over the last twenty years. A key challenge for the Government is that peatland management remains a contested policy area in Indonesia with a range of claims in relation to the 'sustainability' of peatland drainage for plantations. In particular, a management approach known as '*eko-hidro*' has been promoted as sustainable by a number of industry actors and academics. In contrast, the peer-reviewed scientific literature concludes that all peat drainage is associated with subsidence, fire risk and high carbon emissions. Given that a strategic approach for peat restoration and management must have a rigorous scientific and technical base, this report considers the evidence regarding the sustainability of the '*eko-hidro*' approach, highlights its strengths and weaknesses. Based on this review, the report concludes by providing recommendations for peatland management and restoration in Indonesia.

The '*eko-hidro*' peatland management approach was first presented in a 2010 High Conservation Value Assessment study of the Kampar Peninsula in Riau (hereafter the Kampar HCVA Report). It was used as the basis for land use zoning and water management that would ensure "sustainable management" of this extensive peatland landscape (Tropenbos-APRIL-MOF 2010) and has become influential in the development of national policies for peatland management. It consists of three elements:

1) A core conservation area on top of peat domes covering roughly 30 % of the peat area. This conservation area would operate as a natural 'water tower' that would help keep water levels in the lower-lying plantations from falling too low in the dry season;

2) A controlled drainage system with water levels in plantations managed at between 0.5 to 0.8 m below the peat surface to minimize peat loss and thereby reduce carbon emissions and land subsidence;

3) Buffer zones between plantations and conservation forest, of 1.2 to 1.6 km wide, where water levels are kept at a progressively higher level from the plantation to the forest.

The Kampar HCVA report focused on the issue of subsidence due to drainage and claimed that the maintenance of water levels at 0.5-0.8 m below the peat surface as specified by *'eko-hidro'* would reduce subsidence to the extent that it could be considered negligible and therefore sustainable. Two lines of evidence were presented to support the expansion of drained plantations with *'eko-hidro'* water management practices:

- A scenario analysis that concluded that the expansion of plantations (the Kampar Ring) in conjunction with improved water management practices could perform as well at mitigating subsidence as the status quo (i.e., the poor management practices that were standard across plantations at that time);

- Comparison of observed subsidence data that suggested implementation of *'eko-hidro'* water management reduced subsidence from 5-6 cm per year to 3-4 cm per year.

This policy brief concludes that these two lines of evidence are not scientifically robust and do not provide evidence to support the claim that *'eko-hidro'* is a sustainable management approach. Specifically:

- The scenario analysis failed to consider an important alternative scenario of no further plantation expansion combined with improved water management practices, and;

- The data on observed subsidence rates of 5-6 cm per year and 3-4 cm per year were all collected under *'eko-hidro'* water management conditions, so the conclusion that *'eko-hidro'* can significantly reduce subsidence is not supported.

The claim for the sustainability of *'eko-hidro'* as presented in the Kampar HCVA report therefore lacks a clear and scientifically robust basis. Importantly, in view of the fact that all studies have found annual subsidence rates of between 3 to 6 cm even under best plantation water management practices, **it can be concluded that the '*eko-hidro*' and controlled drainage water management systems do not provide an option for**

sustainable peatland management but ultimately lead to significant loss of peat in line with studies of peatlands globally.

The Kampar HCVA Report also used the '*eko-hidro*' approach to consider two important issues for peatland management.

Firstly, it looked at the long-term impacts of land subsidence as a result of peatland management but in this respect, it suffers from an important methodological flaw. The report forecasts long-term subsidence using data from the first few years after drainage when physical subsidence processes (i.e. compaction) are dominant, which leads to a decline in initial subsidence rates. Projection of this declining subsidence rate is inappropriate in a plantation setting where water levels will be managed at a specific target level. In reality, the rate of subsidence after the first few years in a plantation setting has been shown to be more or less constant and dependent on water management. This means that the conclusion of the Kampar HCVA report, like a similar analysis of subsidence on Pulau Padang, that subsidence will have no impact for centuries and so can be ignored is wrong. A recent study of the impacts of subsidence on the Kampar Peninsula shows that even with best '*eko-hidro*' water management practices, a conservative estimate of subsidence rate of 3.5 cm per year will lead to drainage problems and flood risk within decades (see Hooijer et al. 2015).

The second issue addressed by the Kampar HCVA Report is that of land use planning on peatland. Since 1990 national land-use policies have protected peat with a depth of more than 3 meters (e.g. Presidential Decree 32/1990, Government Regulations 47/1997 and 26/2008) that, if applied, would protect the majority of the Kampar Peninsula including areas developed for plantations. The Kampar HCVA Assessment claimed that with '*eko-hidro*' water management practices, only a central core area of roughly 30 percent of the peatland should be protected. This approach has two major problems:

1) The '*eko-hidro*' approach to land use zoning assumes that this core area would function as a source of water for surrounding peatland and plantations in the dry season thus ensuring that water levels remained at the target level. The assumption seems to be that this will occur through groundwater flow but the reality is that such flow yields less than 5 percent of the water volume required to significantly mitigate the fall in dry season water levels in surrounding plantations. This means that the impact on water level control in production zones will be insignificant when such large productive zones are created. A much larger area of peatland must be protected in order to meet the goal of this approach;

2) The second issue with this approach is that the flow of groundwater from the conservation zone to the production zone would itself lower the water levels in the conservation zone and have a major impact on peat and forest health,

compromising the 'conservation' status of the forest. This would cause, in time, increase tree fall and mortality in the conservation core and carbon emissions from peat oxidation. A conservation zone on peatlands should be just that with water levels maintained as high as possible all year round, and not drawn down in the dry season as proposed by the *'eko-hidro'* approach.

The '*eko-hidro*' concept of protecting a central peatland area appears to be in part based on an unrealistic representation of peatland morphology with a raised central zone considered to be the peat dome as presented in the Kampar HCVA study (see Figure 1). Raised ombrotrophic peatlands are in fact much flatter and the peat dome actually consists of **all** the peatland that lies above the surrounding land and ground water, which in a domed, ombrotrophic (i.e. rain-fed) peatland accounts for most of the peatland area. It is clear that in most of Indonesia's ombrotrophic, raised peat lands that the peat dome will account for a large proportion if not all of the total peat area.

The question remains whether controlled drainage with water levels as high as 0.4 m below the peat surface as legislated in Government Regulation 71/2014 can enable sustainable peatland management. The relationship between water levels and observed subsidence in Acacia plantations on the Kampar Peninsula shows subsidence rates of about 5 cm per year under the '*eko-hidro*' target water level (Hooijer *et al*. (2012)). If water levels are raised to 40 cm, this would reduce subsidence marginally, to 3.5 cm per year, a reduction of 26 percent. As Hooijer et al. (2015) show, this is still associated with long-term problems of drainability and flooding in the Kampar Peninsula in a matter of decades, and so cannot be considered sustainable.

Our assessment concludes that '*eko-hidro*' and controlled drainage cannot prevent the long-term impacts of peatland drainage, but can only slow down the process of subsidence and partially reduce emissions from peat oxidation and the risk of fires. As a result, '*eko-hidro*' cannot be considered a sustainable or even a responsible management system when applied across extensive deep peatland areas as recommended by the Kampar HCVA Assessment. It neither presents a credible alternative to peat restoration, nor contributes to policy that limits the impacts of drainage, including fire risk, subsidence and GHG emissions, on Indonesia's extensive deep peatlands.

Subsidence is an inevitable consequence of peatland drainage regardless of whether the water table is managed at 40 cm or 50-80 cm. The only truly sustainable peatland water management and production system is one that is based on undrained or rewetted peat where water levels will be close to the surface and which has a permanent cover of vegetation – only under these circumstances can subsidence be halted. Such production systems using species adapted to wet peat soils urgently need to be developed in the context of peatland management in Indonesia.

These conclusions need to be considered by policy makers and land managers in the design of interventions to reduce fire risk and the impacts of drainage across peatlands as part of Indonesia's national peatland management and restoration program. As a consequence, this report recommends the following:

Recommendation 1 – Addressing subsidence, flooding, emissions, and dry season fire risk will require the phasing out of drainage, including *'eko-hidro'* and other controlled drainage systems, in the majority of Indonesia's peatlands.

While water management of peatlands is key to their management, the limitations of water management and controlled drainage are not fully recognized. A peatland that is drained will inevitably experience lower than natural water levels, significant subsidence as well as an elevated fire risk during long periods of low rainfall. Only by maintaining near-natural water levels (i.e. as high as possible) will these risks be minimized. Over time, peatland drainage will need to be phased out and alternative commercial species adapted to rewetted peatland phased in.

Recommendation 2 - A new approach to land use zoning for Indonesia's peatlands is required based on current drainage condition, land cover, biodiversity and economic considerations.

A new approach to peatland land use zoning urgently needs to be defined that classifies peatland landscapes to ensure (a) effective protection and restoration of peatland landscapes that have high conservation values or reasonable restoration potential, and (b) best practice management of peatland landscapes that are heavily degraded, have only limited peat remaining due to loss of peat from subsidence through burning and drainage and that will be difficult to restore.

In peatland landscapes with conservation value and potential for restoration, four land use zones should be defined:

- **Protection zone with full protection (*kawasan lindung*)** – Areas that should be protected, restored and actively managed according to the current definition of protection zone;

- **Rewetted peat production zone (*kawasan budidaya gambut basah)* -** Production on restored and rewetted peat using native species adapted to wet peatland conditions under natural forest (e.g. ecosystem restoration) or timber and peatland adapted agricultural plantations (e.g. paludiculture);

- **Limited peat production zone (*kawasan budidaya gambut terbatas*) -** Production on drained peat with a time limit for future restoration and rewetting and conversion of wet peatland production systems – the time limit for when restoration should begin should be established through drainability assessments as mandated by the RSPO;

- **Peat production zone (*kawasan budidaya gambut tetap*)** - Production on drained peat with no time limit for its restoration – this peat will eventually be lost, and large parts of the landscape will become undrainable, flood prone and unproductive. These areas would include peat located in peat landscapes without conservation value and potential for restoration.

Recommendation 3 - Expand the focus of peatland restoration beyond previously burnt areas to include (a) natural forest areas as a priority for restoration and (b) all peatland areas in the context of the new approach to land use zoning proposed in this report.

The focus on peatland restoration and water management options risks shifting attention away from the management of peatland areas with natural forest cover. As the 2015 fires have shown, these areas are also at high risk of burning and a priority should be placed on maintaining the remaining natural forest on peatlands. This includes degraded forest areas that have experienced or are experiencing logging, agricultural encroachment and plantation expansion, where forest protection and enforcement operations will need to be increased, as well as forest areas that have canal networks associated with past logging operations. As practically all remaining peat swamp forest is located on deep peat in Sumatra and Kalimantan, these areas should be legally protected and prioritized for restoration where needed. Peatland restoration should therefore be targeted beyond the 2 million hectares of peatland burnt in the 2015 fires to peatland with natural forest cover and priority unmanaged and plantation peatland areas.

Recommendation 4 - Policies for peatland management and restoration need improved definitions that (a) differentiate domed peatlands from valley and watershed peats and (b) within domed peatlands, provide a clear legal basis for the spatial delineation of the peat dome.

The vast majority of Indonesia's peatland exists as raised domed (ombrotophic) peatlands that are mostly located in the coastal lowlands of Sumatra, Kalimantan and Papua. However, not all peatlands in Indonesia exist as peat domes, some occur as watershed or valley peats in non-tidal lowlands and hilly to mountainous landscapes (Andriesse 1974). These peatlands are hydrologically different and will require different policies to regulate their management and use. Peatland inventory should therefore classify the type of peatland landscape differentiating raised dome peatland landscapes from valley or watershed peat.

A proper legal definition of a peat dome is required that provides the basis for management and restoration. Current regulations such as PP71/2014 do not explicitly define the peat dome but refer to it in the context of land use zoning. The peat dome should be legally defined as the total area of peat that lies above the surrounding mineral landscape and which receives its water solely from rainfall.

1. Introduction

The Government of Indonesia is taking important steps to address the extensive drainage of peatlands that has been a key factor in the expansion of forest and land fires and related haze over the last twenty years. Foremost amongst these is the creation of a new Peatland Restoration Agency (*Badan Restorasi Gambut, BRG*) that is tasked with the restoration of 2 million ha of degraded, burnt peatland (Presidential Regulation 1/2016). Peatland restoration is an important action to reduce future fire risks but will only be effective with complementary measures to manage adjacent peatland areas, in particular drained plantations, as part of an integrated water and landscape management approach for peatlands.

A key challenge for the Government is that peatland management remains a contested policy area in Indonesia with a range of claims in relation to the 'sustainability' of peatland drainage for plantations.[1] The peer-reviewed scientific literature highlights that peatland drainage is associated with a cycle of fires and floods that result from the drying out and subsidence of drained peatland: in long dry seasons, drainage creates significant fire risk, while on-going land subsidence from drainage will over time make peatland areas increasingly flood prone in the wet season (Stephens et al. 1984, Andriesse 1988, Wosten et al. 1997, Hooijer et al. 2015). In short, any form of peatland drainage is unsustainable and will lead to the loss of peat with factors such as temperature and drainage depth determining the rate of loss. Theoretical and empirical studies globally show that peat subsidence from drainage will be highest in deeply drained tropical peatlands (e.g. Stephens et al. 1984, Hooijer et al. 2012, Galloway et al. 2016).

[1] There are a number of definitions of sustainable resource management. Definitions based on weak sustainability consider that human, financial and natural capital are substitutable, with sustainability being assessed based on the total stock of capital. Strong sustainability definitions consider that natural capital provides society a specific set of goods and services that cannot be substituted. Peatland drainage leads to the long-term loss of peat and its ecosystem goods and services (i.e. peatland ecosystem function) and is therefore unsustainable based on strong sustainability criteria. Peatland management policies in Indonesia (i.e. PP71/2014) are aimed at preserving ecosystem function, and therefore are based on a strong sustainability definition.

A prominent, alternative claim reported in the media in Indonesia is that an approach to peatland water management known as '*eko-hidro*' is a sustainable management system that will keep peat wet and minimize peat land fires, while enabling the production of plantation crops that require drainage such as oil palm and the pulp crop, *Acacia crassicarpa*.[2] This claim is contentious as it contrasts with empirical studies of peatland drainage both in Indonesia and on all comparable domed peatlands elsewhere in the world that show peatland drainage, even with controlled drainage water management systems such as '*eko-hidro*', is economically and environmentally unsustainable and associated with long-term land subsidence, the loss of agricultural production and increased fire risk (e.g. Andriesse 1988, Verhoeven & Setter 2009, Deverel et al. 2016, Erkens et al. 2016).

The '*eko-hidro*' approach has been promoted by a number of industry actors and academics, and has been regularly referred to by government in the context of peatland water management in Indonesia. Despite the importance of this issue, the claims of the positive effects of the '*eko-hidro*' management approach have received limited technical and scientific substantiation, and there are no peer-reviewed scientific publications that provide analysis of any '*eko-hidro*' field results. Given that a strategic approach for peat restoration and management must have a rigorous scientific and technical base, this report considers the evidence regarding the sustainability of the '*eko-hidro*' approach, highlights its strengths and weaknesses and provides recommendations for peatland management and restoration in Indonesia.

[2] See, for example, http://klikriau.com/read-17848--rapp-terapkan-teknologi-ekohidro-atasi-kebakaran-gambut.html.

2. The '*eko-hidro*' peatland management approach and the Kampar HCV Assessment

The '*eko-hidro*' peatland management approach was first presented in a 2010 High Conservation Value Assessment study of the Kampar Peninsula in Riau (hereafter the Kampar HCVA Report) as the basis for land use zoning and water management that would ensure "sustainable management" of this extensive peatland landscape (Tropenbos-APRIL-MOF 2010). The '*eko-hidro*' peatland water management system is essentially a system of controlled drainage with buffer zones combined with peatland land use zoning that aims to mitigate the impacts of drainage across the peatland landscape.

The land use zoning and '*eko-hidro*' peatland water management approach presented in the Kampar High Conservation Value Area (HCVA) report consists of three main parts:

1. **A core area of conservation forest on top of peat domes** is to be maintained and protected covering roughly 30 % of the peat area. Water flowing out of these conservation areas would help keep water levels in the lower-lying plantations from falling too low in the dry season.
2. **A controlled drainage system** with canals following contours and water levels in plantations managed at between 0.5 to 0.8 m below the peat surface to minimize peat loss and thereby carbon emission and land subsidence.
3. **Buffer zones between plantations and conservation forest**, of 1.2 to 1.6 km wide, where water levels are kept at a progressively higher level from the plantation to the forest to allow water levels in the conservation forest to follow a natural regime, to mitigate drainage impacts on surrounding natural forest areas (see Table 1).

Table 1. Buffer zone specification for 'eko-hidro' water management system. 'Water Level' refers to water level below the peat surface.

Area	Slope Area		Flat Area	
Buffer zone width	1.2 km		1.6 km	
Zone	**Width**	**Water Level**	**Width**	**Water Level**
Natural forest	-	0 cm	-	0 cm
Native species	400 m	0-15 cm	400 m	0-10 cm
Melaleuca I	400 m	15-30 cm	400 m	10-20 cm
Melaleuca II	-	-	400 m	20-30 cm
Acacia buffer	400 m	30-45 cm	400 m	30-45 cm
Acacia / normal plantation	-	50-80 cm	-	50-80 cm

Source: (Tropenbos-APRIL-MOF 2010)

3. Evidence on the Impacts of *Eko-Hidro*

The Kampar HCVA report presented the '*eko-hidro*' water management system as the basis for the sustainable management of the Kampar Peninsula peatland. The empirical evidence regarding the benefits of '*eko-hidro*' and improved water management presented in the report was based on three main sources: (1) Science-based Management Support Project (SBMSP) [3] data and analysis on subsidence and water table depth; (2) data collected by PT RAPP (APRIL), and; (3) analysis by the Kampar HCVA hydrology team.

The Kampar HCVA report focused on the issue of subsidence due to drainage and claimed that the maintenance of water levels at 0.5-0.8m below the peat surface as specified by '*eko-hidro*' would reduce subsidence to the extent that it can be considered negligible and therefore sustainable. It presented this in terms of future subsidence scenarios based on four management regimes and the empirical data referred to above.

Subsidence Scenarios - In 2005, Proforest and Deltares completed a preliminary analysis of four different management scenarios on peat subsidence on the Kampar Peninsula (see Proforest 2005). These management scenarios were: (1) the current situation i.e. no further development or drainage, (2) expansion of plantations (the Kampar Ring) and current water management practices, (3) expansion of plantations (the Kampar Ring) and improved water management practices to mitigate impacts, and (4) expansion of plantations (the Kampar Ring), current water management practices and additional plantation development. This analysis showed that scenario 3 - expansion of plantations (the Kampar Ring) and improved water management practices – had the lowest level of future subsidence.

[3] SBSMP was an advisory project developed and implemented by Deltares, University of Leicester, Proforest, University of Helsinki and Wageningen University for APRIL. See: https://www.wetlands.org/publications/kampar-peninsula-science-based-management-support-project/

The Kampar HCVA report concluded that scenario 3 was the "best solution" for the management of the Kampar Peninsula because it did not differ too much from scenario 1 (Book I, p. 94). This conclusion is, however, not in line with the Proforest and Deltares recommendation because the four scenarios were not defined to determine the 'best solution' for the management of the Kampar Peninsula, but to illustrate the likely effect of four alternative land use scenarios. It is clear that a scenario of no further plantation expansion combined with improved water management practices would have been a better solution from the perspective of subsidence impacts, but that this and other alternative management options including, for example, Ecosystem Restoration and REDD+ were not evaluated in these potential management scenarios.

Empirical Data on Subsidence Rates - The Kampar HCVA report identifies subsidence as a problem, both within drained plantations and forest areas outside of the drained plantation. The Kampar HCVA report presents data on subsidence from SBSMP at Estate J and K from 2002 to 2008. The report states that subsidence of 60 cm occurs in the first year after drainage and then declines to a stable level of 5-6 cm per year (Book I, p. 116-117). The average subsidence in the first seven years is 133 cm or 17 cm/year with an estimated 50cm of subsidence due to consolidation with a further 30cm due to compaction.[4] In monitoring conducted in 2008-2010, subsidence of 5cm per year was recorded by SBSMP excluding subsidence caused by harvesting and extreme dry years (see also Hooijer et al. 2012). In conservation forest adjacent to the plantation impacted by plantation drainage, SBSMP found annual subsidence of 2.2 cm (6.5 cm over three years) with a range from 1.5 to 4.2 cm.

The Kampar HCVA report also presents data on subsidence from the PT RAPP Water Management section and Kampar HCVA team that was initiated in 2007. These show average annual subsidence rates of 3.3 cm and 3.7 cm for 35 monitoring locations measured by PT RAPP and 3.0 cm for 13 locations measured by the HCVA team in Acacia plantations. These results are lower than the subsidence measurements from SBSMP and the report concludes that this difference is due to improved water management (Book I, p.117).

[4] The physical processes of consolidation and compaction both make a significant contribution to the high rates of peatland subsidence in the initial years following drainage. After several years, subsidence rates decline and are driven almost entirely by biological processes (oxidation of aerated, oxic peat). It is important to note that peat oxidation and subsidence will gradually decline over time (possibly decades) as the peat surface moves closer to the below ground water table. This will require plantation water managers to gradually lower water levels to maintain conditions suitable for crop growth, which result in a relatively constant rate of subsidence over the long-term until the drainability limit is reached.

This conclusion is not correct as SBSMP monitoring conducted during 2008-2010 that found subsidence of 5cm per year was actually for peatland management under best water management practice conditions (i.e. the '*eko-hidro*' management system), where an average ground water table depth of 0.7 m was achieved. The peer reviewed scientific publications that came from SBMSP (Hooijer et al 2012; Jauhiainen et al 2012) are based on studies in APRIL's 'best management' pilots and contradict the '*eko-hidro*' claims by showing that land subsidence and carbon emissions, at rates of 5 cm yr^{-1} and 75 t CO2 yr^{-1} respectively, remain high even with a groundwater table depth of 0.7 m. The SBMSP findings, while being published and accepted widely in scientific circles including IPCC, have so far been ignored in discussions of peatland water management and '*eko-hidro*'.

In sum, the evidence for the sustainability of *eko-hidro* as presented in the Kampar HCVA report lack a clear and scientifically robust basis. Importantly, in view of the fact that all studies found subsidence of between 3 to 6 cm, **it can be concluded that the '*eko-hidro*' water management system does not provide sustainable peatland management but ultimately leads to significant loss of peat in line with studies of peatland globally.**

4. The Long-term Impacts of Subsidence

Over the long-term, the drainage of peatlands is recognized to cause long-term subsidence that can only be stopped by the ending of drainage and peatland restoration to raise water levels to near the peat surface (Stephens et al. 1984, Galloway et al. 2016). A key impact of subsidence following peatland drainage is to move the peat surface closer to the water level so that over time, land managers must further drain the peat by deepening canals to maintain water levels relative to the peat surface that are optimal for crop growth.[5] This 'race to the bottom' ends when so much peat has been lost that the peatland can no longer be drained by gravity, or if management is ended and the peat subsidence declines to zero as peatland establishes a new equilibrium (Dommain et al 2010). While subsidence rates will vary over the space of a few years, over the long-term subsidence in managed plantations will be broadly linear until the peatland can no longer be drained and water levels rise. Andriesse (1988) considered this issue and recommended a reclamation potential assessment be completed to assess the potential for long-term production.

Hooijer et al. (2015) apply published annual long-term subsidence rates for managed plantations of 3.5 cm and 5 cm to an elevation model of the Kampar Peninsula peatland. This study found that within 25, 50 and 100 years, 71%, 83% and 98% of the existing plantation area is projected to experience drainability problems and/or flooding. Smallholders located on the lower peat areas closer to river would be the first and most severely affected group of peatland land users. This study highlights that peatland drainage is unsustainable over the long-term and that significant impacts are likely already being experienced and will only get worse in the coming decades.

[5] In the absence of continued management to deepen drainage canals, the peat surface will subside towards the water level in the peatland. As this happens, subsidence will gradually decline until water levels are lowered.

The Kampar HCVA Assessment considers this issue yet comes to a different conclusion to Hooijer et al. (2015) (see Book I, Kampar HCVA Assessment, p. 91). The Kampar HCVA Assessment uses subsidence data for the six years after drainage to fit a logarithmic relationship between subsidence rate and time. A logarithmic relationship shows a steady decline in the rate of subsidence with time, so the Kampar HCVA Assessment concludes that the lifetime of the plantation can be measured in hundreds of years. This approach to modeling and projecting subsidence is, however, flawed because the Kampar HCVA Assessment uses primary subsidence data covering the first years following drainage to project secondary subsidence rates. [6] As physical compaction and consolidation rapidly decline in following drainage, primary subsidence rates decline over time. In contrast, secondary subsidence rates are mostly dependent on water levels, and assuming water levels are broadly constant as would be expected in a managed plantation, then subsidence rates too would also be relatively constant over time. This same problem exists with the analysis of subsidence on Pulau Padang by Kalsim (2012) that concludes subsidence will not be a problem associated with peatland drainage on Pulau Padang.

In sum, the analysis of long-term subsidence in the Kampar as presented in the Kampar HCVA Report has an important methodological flaw that has led to an erroneous conclusion regarding the long-term impact of subsidence on ombrotrophic peatland in Indonesia. As illustrated by Hooijer et al. (2015), these impacts of the loss of drainability and increased flood risk are likely already being experienced in the wet season and will become more severe in the coming decades, much faster than implied by the Kampar HCVA Assessment and associated studies.

[6] The process of subsidence in peatland can be separated into primary subsidence in the first few years following drainage that is dominated by physical processes and secondary subsidence in the subsequent years that is dominated by biological oxidation.

5. The Use of Eko-hidro for Land Use Planning on Peatland

The Kampar HCVA Assessment also applied the *eko-hidro* approach for land use planning on peatlands. Current policies protect peat with a depth of more than 3 metres that would include the majority of the Kampar Peninsula including areas developed for plantations if applied. These policies have existed since 1990 and include Presidential Regulation 32/1990, the 1997 National Spatial Plan (PP47/1997) and the 2008 National Spatial Plan (PP26/2008). The Kampar HCVA Assessment claimed that with '*eko-hidro*' water management practices just a central core area of roughly 30 percent of the peatland should be protected, a criterion that has been used in the recent Government Regulation on Peatlands (PP 71/2014). This approach has two major problems.

Firstly, the '*eko-hidro*' approach to land use zoning assumed that this core area would function as a source of water for surrounding peatland and plantations in the dry season and ensure that water levels remained at the target level.[7] The assumption seems to be that this will occur through groundwater flow but the reality is that such flow occurs only over a few kilometers and yields only a tiny fraction of the water volume required to significantly mitigate the fall in dry season water levels in surrounding plantations. Mawdsley et al. (2013) highlight that the Kalsim (2009) water balance model, on which the prescription of protecting 30 percent is based, ignores Darcy's Law, which accounts for resistance of the peat on ground water flow and needs to be applied in such circumstances.[8] Application of Darcy's Law to the Kalsim (2009) water balance model shows that under a variety of conditions, a core conservation area covering 30 percent of the peatland can only supply the equivalent of less than 5 percent of the total dry season water deficit on production zones (see

[7] This approach to land use planning in peatland is based on Kalsim (2009).

[8] Darcy's law is an equation that describes how a fluid flows through a porous material such as peat.

Annex 4 of Mawdsley et al. 2013). This means that the impact on water level control in production zones will be insignificant when such large productive zones are created. A much larger area of peatland must be protected in order to meet the goal of this approach.

The second perhaps more fundamental issue with this approach is that the flow of groundwater from the conservation zone to the production zone would itself lower water levels in the conservation zone and have a major impact on peat and forest health, compromising the 'conservation' status of the forest. This would cause, in time, increased tree fall and mortality in the conservation core. A conservation zone on peatlands should be just that with water levels maintained as high as possible all year round.

The '*eko-hidro*' concept of protecting a central peatland area appears to be in part based on an unrealistic representation of peatland morphology with a raised central zone considered to be the peat dome as presented in the Kampar HCVA study (see Figure 1). Raised ombrotrophic peatlands are in fact much flatter and the peat dome actually consists of **all** the peatland that lies above the surrounding land and ground water, which in a domed, ombrotrophic (i.e. rain-fed) peatland accounts for most of the peatland area. [9] If the peat dome is to be protected from drainage due to its dependence on rainfall as its sole source of water, then the peat dome must be clearly defined and delineated. It is clear that in most of Indonesia ombrotrophic, raised peat lands that the peat dome will account for a large proportion of the total peat area.[10]

The Kampar Peninsula should in fact be considered as a single raised peat dome (see Figure 1, bottom), representing the typical kind of domed peatland of lowland western Indonesia. Within the Kampar peat dome, which forms a single hydrological unit, some sub-domes (i.e. areas with somewhat deeper peat) can be differentiated. These sub-units are defined by natural drainage features (black water rivers) of the

[9] The term 'peat dome' refers to the fact that all ombrotrophic (rain-fed) peatlands are raised in a dome above the surrounding landscape and ground water. The term 'raised bog' is also used to describe such ombrotrophic peatlands in temperate. Dommain et al. (2010) compare the functioning of temperate raised bogs with tropical peat domes and conclude that both are controlled by the same self-regulating mechanisms characterised by the relationship between peat, water and vegetation.

[10] Indonesia defines a peatland hydrological unit (*kesatuan hidrologi gambut*, KHG) as the basis for the management of peatland landscapes. For raised peat domes, each KHG will contain (i) mineral levees and soils close the rivers, (ii) shallow peat soils as a transition zone between the mineral soils and may be more influenced by groundwater than rainfall (also termed the peat lagg (e.g. Howie & Tromp-van Meerveld 2011) and (iii) the raised ombrotrophic peat dome.

dome, which developed as secondary features during peatland development (i.e. they flow over and are entirely contained within the peatland landscape). However the Kampar HCVA report suggests that there are three separate domes on the peninsula, ignoring the interconnected peat soil and hydrological connections. If zoning is undertaken with the view that these are separate hydrological systems, it will lead to drainage in one area impacting the broader landscape. Subsidence of one sub-dome will inevitably impact the other sub-domes due to the hydrological connectivity of the whole landscape.

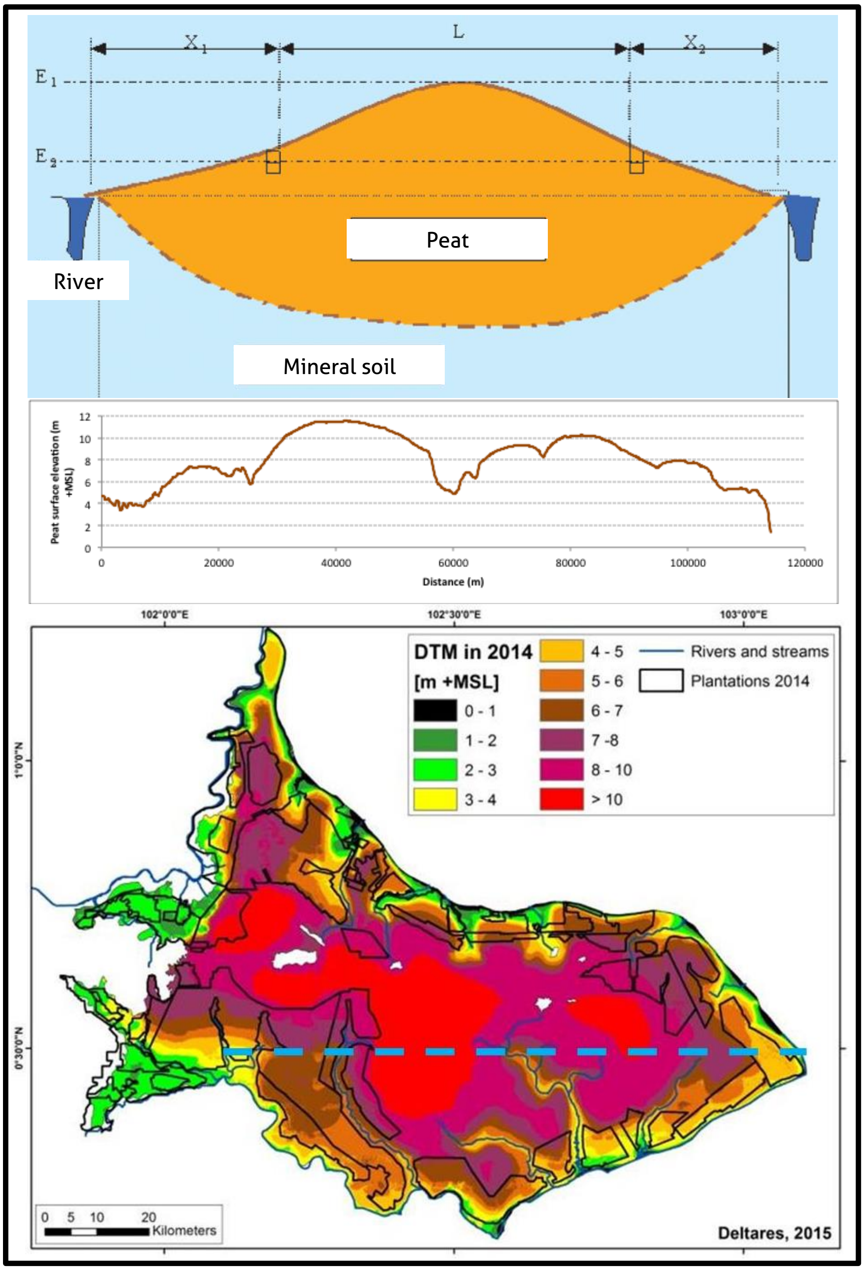

Figure 1: *Peatland morphology as shown in the eko-hidro model (Top), actual cross section (East-West profile) of the Kampar Peninsula derived from LIDAR (Middle) and the Digital Terrain Model showing the elevation of the Kampar Peninsula, the plantations (black line) and cross section (dotted line) (Bottom; Hooijer et al. 2015)*

6. Can controlled drainage provide the basis for sustainable peatland management?

The question remains of whether controlled drainage with higher water levels such as 0.4m as legislated in Government Regulation 71/2014 can enable sustainable peatland management. Hooijer et al. (2012) present an empirical relationship between secondary subsidence (i.e. after the first six years of drainage) and water level that enables this to be assessed.[11] With an average water level of 65cm as proposed by the '*eko-hidro*' water management system, the expected subsidence rate is 4.7cm per year. If water levels are raised to 40cm, this would reduce subsidence but only to 3.5 cm per year, a reduction of 26 percent. As Hooijer et al. (2015) show, this is still associated with long-term problems of drainability and flooding in the Kampar Peninsula in a matter of decades, and so cannot be considered sustainable.

At least on very deep peat, the impacts of drainage are also likely to extend at least 2km from the plantation boundary and require a wider buffer zone than proposed in the *eko-hidro* approach for protection of adjacent undrained peatland to be effective (Hooijer et al. 2012). Such a buffer zone is critical to reducing impacts of drainage from plantations to unmanaged peatland that are associated with increased fire risk outside of the plantation.

[11] The relationship between the secondary subsidence rate and water table for drained plantations given by Hooijer et al. (2012) is $S = 1.5 - 4.98 \times WD$, where S = subsidence rate (cm yr^{-1}) and WD = average water table depth below the peat surface (-negative, m).

7. Conclusions

This report has assessed the claims of the '*eko-hidro*' controlled water management approach and found that it can make only a limited contribution to reducing carbon emissions or subsidence rates. The assessment concludes that '*eko-hidro*' cannot prevent the long-term impacts of peatland drainage, but instead can only slow down the process of subsidence and partially reduce emissions from peat oxidation and the risk of fires. As a result, '*eko-hidro*' cannot in any way be considered a sustainable or even a responsible management system when applied across extensive deep peatland areas as recommended by the Kampar HCVA Assessment. It neither presents a credible alternative to peat restoration, nor contributes to policy that limits the impacts of drainage on Indonesia's extensive deep peatlands.

The SBMSP scientists who also considered this in the context of the Kampar Peninsula and the findings of the Kampar HCVA Assessment concluded that drained plantations on tropical peatland are fundamentally unsustainable [i] economically, because most land will eventually be flooded and unproductive (see also Hooijer et al. 2015), [ii] environmentally, because there is no way to substantially reduce annual carbon emissions (and insofar as any reduction is possible, it is just a postponement of a limited proportion of emissions by some decades at best), and [iii] ecologically, as the degradation of peat swamp forest up to several kilometers from a drained plantation appears inevitable.

Subsidence is an inevitability of peatland drainage regardless of whether the water table is managed at 40cm or 50-80cm. The only truly sustainable peatland water management and production system is one that is based on undrained or rewetted peat where water levels will be close to the surface and subsidence will be close to zero. Such production systems using species adapted to wet peat soils urgently need to be developed in the context of peatland management in Indonesia. The only alternative is to continue with peatland drainage including through controlled drainage systems such as '*eko-hidro*' and accept the negative impacts and long-term damage caused by these and all drainage systems.

These conclusions need to be considered by policy makers and land managers in the design of interventions to reduce fire risk and the impacts of drainage across peatlands as part of Indonesia's national peatland management and restoration program.

8. Policy Implications

The claim that '*eko-hidro*' and other controlled drainage system are sustainable has already made an impact on policies relating to peatland management in Indonesia in relation to land use zoning, target water levels to prevent damage to peatland ecosystems and the Government's response to the 2015 fires.

Land Use Zoning

The Kampar HCVA study and the '*eko-hidro*' approach provided the basis for the designation of the Kampar Peninsula as a production forest landscape management unit (KPHP) with roughly 70 percent of the area zoned for production (and therefore drainage), leaving 30% of the central peat area protected based on the conceptual model for '*eko-hidro*'. This is at odds with spatial planning regulations that prohibit development on peat soils deeper than 3m despite the fact that the area is almost entirely on very deep peat (over 5 m) and should be legally protected.

The management prescription to protect 30 percent of the peatland landscape as proposed by '*eko-hidro*' also appears in the 2014 Government Regulation for the protection and management of peatland ecosystems (PP71/2014) in addition to the protection of peat with a depth of more than three metres. This approach for national policy has four main weaknesses:

1) Protection of 30% of a peat dome is too little to maintain the hydrological functioning of raised peat domes. As this report has made clear, there recommendation of the '*eko-hidro*' model to protect 30% of the peatland is technically flawed. In order to protect and maintain the hydrological function of raised peat domes, which is the policy goal of PP71/2014, a much greater area needs to be protected from drainage;

2) There is no scientific basis for limiting protection to peat more than 3m deep. The choice of 3 meters was established as a pragmatic decision to balance production and the protection of hydrological function in peatland landscapes. Drainage of 2.5 meter, 2 meter or 1 meter deep peat will also lead to the same environmental impacts with regard to flooding - only faster than deeper peatland areas, which can subside for a longer period at the same rate before they will reach the drainage limit. Plantation companies naturally gain benefit from being on the deeper, higher peat as these areas will have an extended lifetime under drainage compared to shallow peat areas (Hooijer et al. 2015);

3) Current land use policies in Indonesia only define two options – full protection (*kawasan lindung gambut*) or full development that allows drainage (*kawasan budidaya*). These land use policies have not been specifically developed for peatlands and do not provide the policy tools that government needs to balance environmental and economic management of peatland ecosystems. In particular, current land use zoning options do not enable the economic use of restored, rewetted peatland more than 3m deep;

4) The application of a standard 'one size fits all' approach to land use zoning to all peatlands will result in a poor outcome – heavily degraded peatland landscapes (e.g. peat in Block D of the Mega Rice project area in Central Kalimantan) will be protected even where there is little chance of restoration.

As this report makes clear, the management prescription that conserving 30 percent of the central area of a peatland landscape would allow it to be managed sustainably through ensuring that water levels in the surrounding 70 percent of drained cultivated peatland meet the prescribed target of 0.5 – 0.8 m is technically flawed. In short, the recommendations of the HCVA study on zoning are not consistent with peatland science and do not provide a scientifically robust basis for defining protection, buffer and production zones on the Kampar Peninsula or other peatlands in Indonesia or elsewhere.

Target Water Levels for Peatland Drainage

Government Regulation 71/2014 has the goal to preserve the function and prevent damage to peatland ecosystems. It prescribes that peatland classified for production should be managed with a water level of 40cm. As this report has shown, this target water level is still associated with subsidence of 3.5 cm per year and so cannot achieve the goal of Government Regulation 71/2014. Furthermore, many in industry are lobbying for this target water level to be relaxed to the prescription of '*eko-hidro*' on the basis that this is sustainable and will achieve the goals of the regulation. Both these prescriptions have ignored the evidence that drainage with these water levels is associated with long-term impacts that will have economic and environmental consequences.

Post-2015 Forest and Land Fire Developments

The President of Indonesia and Minister of Environment and Forestry have issued a number of statements and directives in response to the 2015 forest and land fires that were especially prevalent in peatland regions.[12] These policy directives include (a) a ban on further expansion of timber and agricultural plantations on peatland including within existing licensed areas, (b) government will complete land use zoning to identify protection and production zones on peatland, (c) a ban on planting in burnt areas while restoration plans are finalized, (d) the application of '*eko-hidro*' in existing plantations (S.494/MEN-LHK/2015) and (e) a requirement for forestry and agricultural license holders to put in place water management systems in concessions that includes (i) the blocking of canals in deep peat or peat dome areas that will protect the peat dome, and (ii) the application of controlled drainage in accordance with PP71/2014 in production areas or in areas already planted (S.661/Menlhk-Sekjen/2015).

Although these policy directives are clear in banning further expansion of plantations and drainage on peatland, there have been different instructions regarding water management. '*Eko-hidro*', with its prescription for water levels to be managed at 0.5-0.8m, is referred to in S.494/MEN-LHK/2015, while the subsequent S.661/Menlhk-Sekjen/2015 refers to PP71/2014 that defines a target water level of 0.4m.

As this report makes clear, both these policy prescriptions will not ensure sustainable peatland management. It will be important for the government to complete a thorough review of peatland land use zoning and water management regulations in order to put in place a regulatory system that can effectively meet the policy goals of reducing fire risk and enable long-term responsible peatland management. Minor revision of Government Regulation 71/2014 will not achieve this and its goal to preserve the function and prevent damage to peatland ecosystems.

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[12] For example: Presidential Instruction Number 11 Year 2015 on Improving the Control of Forest and Land Fires; S.494/MEN-LHK/2015 concerning Ban on Clearing Peatland; S.661/Menlhk-Sekjen/2015 concerning Peatland Management.

9. Recommendations for Improved Peatland Management in Indonesia

This report offers the following recommendations to Government on how improvements in peatland management can be best achieved based on the issues addressed in this report.

Recommendation 1 - Eko-hidro and controlled drainage as a water management approach will lead to continued subsidence, flooding, emissions, and fire in dry seasons – addressing these issues will require the phasing out of drainage in the majority of Indonesia's peatlands.

While water management of peatlands is key to their management, the limitations of water management and controlled drainage are not fully recognized. Water levels in peatlands vary greatly in space and time due to a combination of rainfall patterns, drainage and peatland topography. While drainage can be managed, rainfall cannot and, in turn, a peatland that is drained will inevitably experience lower than natural water levels, significant subsidence as well as an elevated fire risk during long periods of low rainfall. Only by maintaining water levels as high as possible will these risks be minimized.

Over time, peatland drainage will need to be phased out and alternative species adapted to rewetted peatland phased in. If drainage-based plantations are to be maintained in certain areas in the short-term, water levels will need to be in line with crop requirements (typically 50-60cm) to optimize production otherwise the result will be low production and high environmental degradation. PP71/2014 defines a target water level of 0.4m, so is likely to result in low production and high environmental degradation. In the medium to long term drainage will need to be phased out to ensure sustainable outcomes, so prior to peat restoration and rewetting in production areas, it is more logical to maintain water levels in line with crop requirements, in particular as raising water levels from 0.5-0.6m to 0.4m will have limited impact on fire risk and subsidence.

This will require the following actions:

- Review the regulations for water management in peatlands to optimize production in existing plantations over the short-term but establishes the phasing out of drainage in peatlands. Indonesia should define a year for the mandatory phasing out of drained plantation on peat in all peatland landscapes classified as 'with conservation value and potential for restoration'.

- Immediate introduction of controlled drainage and hydrological buffer zones within all plantations where drainage is maintained but ensure that this management approach transitions to maintaining water levels as high as possible in priority areas identified for peat restoration (see Table 2).

- Develop and phase in production systems using species adapted to rewetted peatlands. A major R&D effort for the domestication of suitable species and their products is required as part of the policy for peatland restoration (see FAO guidelines/publications on paludiculture).

Recommendation 2 - A new approach to land use zoning for Indonesia's peatlands is required based on current drainage condition, land cover, biodiversity and economic considerations.

A new approach to peatland land use zoning urgently needs to be defined that can ensure (a) peatland landscapes that are in a relatively good condition in terms of conservation, hydrological function and future fire risk are effectively protected and restored and (b) peatlands that are heavily degraded, have only limited peat remaining due to loss of peat from subsidence through burning and drainage and have no realistic potential for restoration are not protected.

Such an approach will require two steps:

Step 1 – Classification of status of the peat landscape into (a) those 'with conservation value and potential for restoration' to ensure effective protection and restoration of peatland landscapes that have high conservation values or reasonable restoration potential and (b) those 'without conservation value and potential for restoration' with best practice management of peatland landscapes that are heavily degraded, have only limited peat remaining due to loss of peat from subsidence through burning and drainage and that will be difficult to restore. Criteria such as extent of remaining primary and secondary natural forest, remaining peat area and depth, drainage extent, time since drainage and potential for restoration based on hydrological modeling can be applied to classify these landscapes. It is expected that there would be relatively few landscapes without conservation value and potential for restoration and that these would include smaller areas of heavily degraded peat.

Step 2a: Peatland landscapes 'with conservation value and potential for restoration' - Land use zoning in these landscapes should define four different peatland land use zones including:

- **Protection zone with full protection (*kawasan lindung*)** – Areas that should be protected, restored and actively managed according to the current definition of protection zone;

- **Rewetted peat production zone (*kawasan budidaya gambut basah)*** - Production on restored and rewetted peat using native species adapted to wet peatland conditions under natural forest (e.g. ecosystem restoration) or timber and agricultural plantations (e.g. paludiculture);

- **Limited peat production zone (*kawasan budidaya gambut terbatas*)** - Production on drained peat with a time limit for future restoration and rewetting and conversion of wet peatland production systems – the time limit for when restoration should begin should be established through drainability assessments similar to the ones as mandated by the RSPO;

- **Peat production zone (*kawasan budidaya gambut tetap*)** - Production on drained peat with no time limit for its restoration – this peat will eventually be lost, and large parts of the landscape will become undrainable, flood prone and unproductive. These areas would include peat located in peat landscapes without conservation value and potential for restoration.

Step 2b – Peatland landscapes 'without conservation value and potential for restoration' - Land use should be focused on production either with or without drainage depending on the local context and policy objectives and the introduction of best practice management. Peatland management should aim to optimize production and minimize the impacts of drainage. Where the long-term drainability limit is being approached or where fire risks remain high, this would include conversion from drainage-based to no drainage production systems that would enable future productive use of these areas.

This approach to zoning enables companies and communities to utilize deforested, degraded peatland but ensures that priority areas are restored and rewetted to maintain hydrological function. Only this approach can balance the protection and prevention of damage to peatland hydrological function and economic use. The consequences of this approach to zoning peatland for existing drained plantations are shown in Table 2.

Table 2. Consequences of proposed peatland land use zoning for existing plantations where the land use is a drained plantation for oil palm or timber crops.

Future land use zoning	Required Action
Full protection	Retirement of plantation, peat restoration and reversion to natural forest
Production on restored and rewetted peat	Peat restoration and conversion to wet peat production system with suitable species
Production on drained peat with a time limit	(1) Controlled drainage best practice management for the specified time period, followed by (2) peat restoration and conversion to wet peat production system with suitable species
Production on drained peat with no time limit	Controlled drainage best practice management – this will eventually lead to the loss of all peat in these areas.

This approach to land use zoning should also include:

- Effective buffer zones need to be established between protection and production zones that can be regulated in the proposed Ministerial Regulation on peatland zoning defined in Article 13 of PP71/2014. These need to be sufficiently wide (more than 2 km), undrained and permanently forested.
- Drainability assessments by independent experts to ensure areas are identified for timely phasing-out of drainage and restoration before they become undrainable, thus flooded and unproductive.

Recommendation 3 - Expand the focus of peatland restoration beyond previously burnt areas to include (a) natural forest areas as a priority for restoration and (b) all peatland areas in the context of the new approach to land use zoning proposed in this report.

The focus on peatland restoration and water management options risks shifting attention from the management of peatland areas with natural forest cover. As the 2015 fires have shown, these areas are also at high risk of burning and a priority should be placed on managing existing natural forest on peatlands. This includes forest areas experiencing illegal logging and plantation expansion, where forest protection and enforcement operations will need to be increased, as well as forest areas that have canal networks associated with past logging operations. Remaining forest areas need cascaded blocking of illegal logging canals and development of rewetting and revegetation of buffer zones. Peatland restoration should therefore be targeted beyond the 2 million hectares of peatland burnt in the 2015 fires to peatland with natural forest cover and priority unmanaged and plantation peatland areas.

As practically all remaining peat swamp forest is located on deep peat in Sumatra and Kalimantan, these areas should be legally protected. Prioritization of their protection will also contribute to reducing future fire-derived greenhouse gas emissions, air pollution (and associated human and economic impacts) and loss of wildlife habitat. Maintaining intact peat swamp forest is much cheaper than restoration and efforts to protect remaining natural forests from the combined threats of illegal logging and plantation expansion need to be enhanced.

Recommendation 4 - Policies for peatland management and restoration need improved definitions that (a) differentiate domed peatlands from valley and watershed peats and (b) within domed peatlands, provide a clear legal basis for the spatial delineation of the peat dome.

The majority of Indonesia's peatland exists as raised domed (ombrotophic) peatlands that are mostly located in the coastal lowlands of Sumatra, Kalimantan and Papua. However, not all peatlands in Indonesia exist as peat domes, some occur as watershed or valley peats in non-tidal lowlands and hilly to mountainous landscapes (Andriesse 1974). These peatlands are hydrologically different and will require different policies to regulate their management and use.

Raised domed peatlands are dependent on rainfall and cannot be drained if they are to maintain their hydrological function. Valley and watershed peats are generally associated with non-tidal rivers and swamps and are dependent solely on groundwater from rivers and the surrounding landscape. Peatland inventory, for example using LIDAR to identify peat domes, should differentiate these types of peatlands as the basis for separate management and restoration policies. Peatland inventory should therefore classify the type of peatland landscape differentiating raised dome peatland landscapes from valley or watershed peat.

A proper legal definition of a peat dome is required that can act as the basis for management and restoration. Current regulations such as PP71/2014 do not explicitly define the peat dome but refer to it in the context of land use zoning. The Kampar HCVA Assessment Report presents an unrealistic model of the peat dome that does not match current scientific understanding and should not form the basis for peatland management and restoration policies. Land use zoning and water management policies should be based on the specific features and condition of each peat dome. The peat dome should be legally defined as the area of peat that lies above the surrounding mineral landscape and which receives its water solely from rainfall. Such a definition could be contained in the implementing regulations of PP71/2014, in particular for peatland inventory.

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