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SCIENTIFIC REPORT

KFCP Heavy Fuel Load Assessment

Line Intersect Method and Heavy Fuel Load Results

Laura Graham, Sherly Manjin, Elba Tri Juni, Matt Waldram, Febrasius Massal, Nasrul Ichsan, Fatkhurohman and Grahame Applegate

Kalimantan Forests and Climate Partnership

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Kalimantan Forests and Climate Partnership

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EXECUTIVE SUMMARY

Fire is a common occurrence on degraded tropical peatlands, resulting in carbon release into the atmosphere, and is one of the main barriers facing tropical peat swamp forest (TPSF) rehabilitation. The Kalimantan Forests and Climate Partnership (KFCP), located in Kapuas District in Central Kalimantan province, undertook efforts to support and work with local communities to reduce fire incidence through a comprehensive fire management strategy. Not all fires can be eliminated. Those fires at greatest risk of prolonged burning in the deep peat, which endanger the forest and the ecosytem and lead to the greatest carbon release, should be the primary target. Surface peatland fires release less carbon than those that penetrate below the surface of the peat.

Research suggests that below-surface peat fires are more likely if a heavy (large) fuel source is available, which will burn long enough and reach a high enough temperature to take the fire below the surface. In other ecosystems it is known that after one to two forest fires, heavy fuel load (HFL; wood material greater than 2.5 cm diameter) becomes high (as the living biomass is killed by the fires); however, after three or more fires, HFL declines (as the HFL is consumed). This study collected data on HFL and on fire history and land cover type in the KFCP area using the 'line intersect method'. HFL was measured at 183 locations across the length and breadth of the peat dome in the site.

The results showed that locations that had burned 1–2 times had greater HFL volume than locations that had never burned. Locations that had burned three or more times had lower HFL volumes than locations that had never burned. There was some statistical significance within this pattern. HFL also showed a relationship with land cover type, with HFL being statistically highest in the 'Swamp' land cover category.

The findings suggest that, while there was a large variation in HFL for each fire history and land cover category, there is a statistically significant relationship between HFL and fire history, similar to the relationship established for other ecosystems. The implications of these findings are discussed in this paper, namely how well fire history and land cover type can predict HFL volume, and consequently the areas at are in theory at high-risk of below-peat surface fires. This will allow these areas to be prioritised in fire management strategies. Other uses of the data (such as dead biomass inventories) and further questions to explore from these (such as the relevance of HFL surface position; surface-lying or penetrating) are also highlighted.

A discussion on future research needs is also provided, which include additional data needs to increase sample size, using the data to calculate aboveground dead wood biomass, and further explanation regarding the large variation for each fire history and land cover category and the numerous low HFL volumes for all categories. Finally, the current data set recorded other features of the HFL apart from volume—such as wood type (root, trunk, branch, etc.) and whether the wood was lying on the surface or penetrating the peat—which could be useful information for further studies. Aspects of HFL location were also recorded: proximity to village and canal, land management and vegetation cover. Further analysis of these data could be undertaken based on these criteria in an effort to explain the large variation within each fire history category.

CONTENTS

ABBREVIATIONS

ANOVA	Analysis of variance
FMTeam	Fire management team
GHG	Greenhouse gas
GIS	Geographic information system
GPS	Global positioning system
HFL	Heavy fuel load
IAFCP	Indonesia-Australia Forest Carbon Partnership
KFCP	Kalimantan Forests and Climate Partnership
MOFor	Indonesian Ministry of Forestry
MWU	Mann-Whitney U (test)
PSF	Peat swamp forest
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
TPSF	Tropical peat swamp forest
UKP4	Presidential Working Unit for the Monitoring and Control of Development (*Unit Kerja Presiden Bidang Pengawasan dan Pengendalian Pembangunan)*

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1 INTRODUCTION

Indonesia has taken a leading role among developing countries in exploring how to reduce greenhouse gas (GHG) emissions through REDD+ (Reducing Emissions from Deforestation and forest Degradation[1]) initiatives. In 2009, Australia and Indonesia established a partnership between both governments through the Indonesia-Australia Forest Carbon Partnership (IAFCP), and the Kalimantan Forests and Climate Partnership (KFCP) to undertake a REDD+ demonstration project on peat swamp forests (PSF) in Central Kalimantan province, Indonesia. For REDD+ to be successful on degraded tropical peatlands, the annual fires that lead to vast carbon emissions must be studied to better understand the causes, volumes and relationships with local land management, and be monitored to determine annual emissions levels. To this end, as part of the research program, staff in the KFCP Fire Management team (FMTeam) collected data and analysis was conducted on, among other aspects, the distribution of heavy fuel loads (HFL) across the KFCP area, and the relationship of these fuel volumes to fire history and land cover.

This report provides an overview of the KFCP project and implementation activities, a brief literature review on tropical peatland degradation and fires, the relationship between fire history and surface HFL, and the implications of HFL for tropical peatland fires (section 1). It then provides a detailed methodological description of the use of the 'line intersect method' for calculating HFL (section 2). Graphical and statistical analyses of the relationships between HFL and fire history, and HFL and land cover, combined with a discussion on the implications of the findings are presented in section 3. The impact of these findings with respect to KFCP's fire management strategy, and important future research directions, are considered in section 4.

1.1 Project background

The activities carried out by the KFCP program took place in an area of approximately 120 000 hectares (ha) of tropical peatlands. The southern section (approximately 50 000 ha) was located in the north-east corner of Block A and the northern section (approximately 70 000 ha) was located centrally within Block E of the former Mega Rice Project in Central Kalimantan (Figure 1.1). Prior to the mid-1990s this area was covered by peat swamp forest (PSF) but is now bisected by a major canal; the two sections of land differ in terms of level of disturbance and forest quality. Block E has one 12 kilometre (km) long canal running north–south impacting upon its hydrology, and has been subjected to concession logging (1980s–1998), illegal logging and numerous small hand-built canals. However, relative to the extensive canal establishment that has occurred in Block A, large sections of the Block E forest remain relatively undisturbed. Block A is criss-crossed by a network of canals 6–10 metre (m) wide with two large 30 m wide canals dividing Block A from Block E. Almost all of Block A, apart from about 5 000 ha, has been deforested or is very badly degraded. Fourteen community settlements are located in the KFCP area along the Kapuas River. These settlements form nine village administrative units (*desa*)[2] that are spread among two sub-districts (*kecamatan*) within the Kapuas district (*kabupaten*).

KFCP activities included assistance to formulate five-year Village Development Plans, opportunities for direct income-generating benefits from small-scale reforestation and rehabilitation activities, an extensive peatland monitoring program, village-level capacity building, self-management and implementation

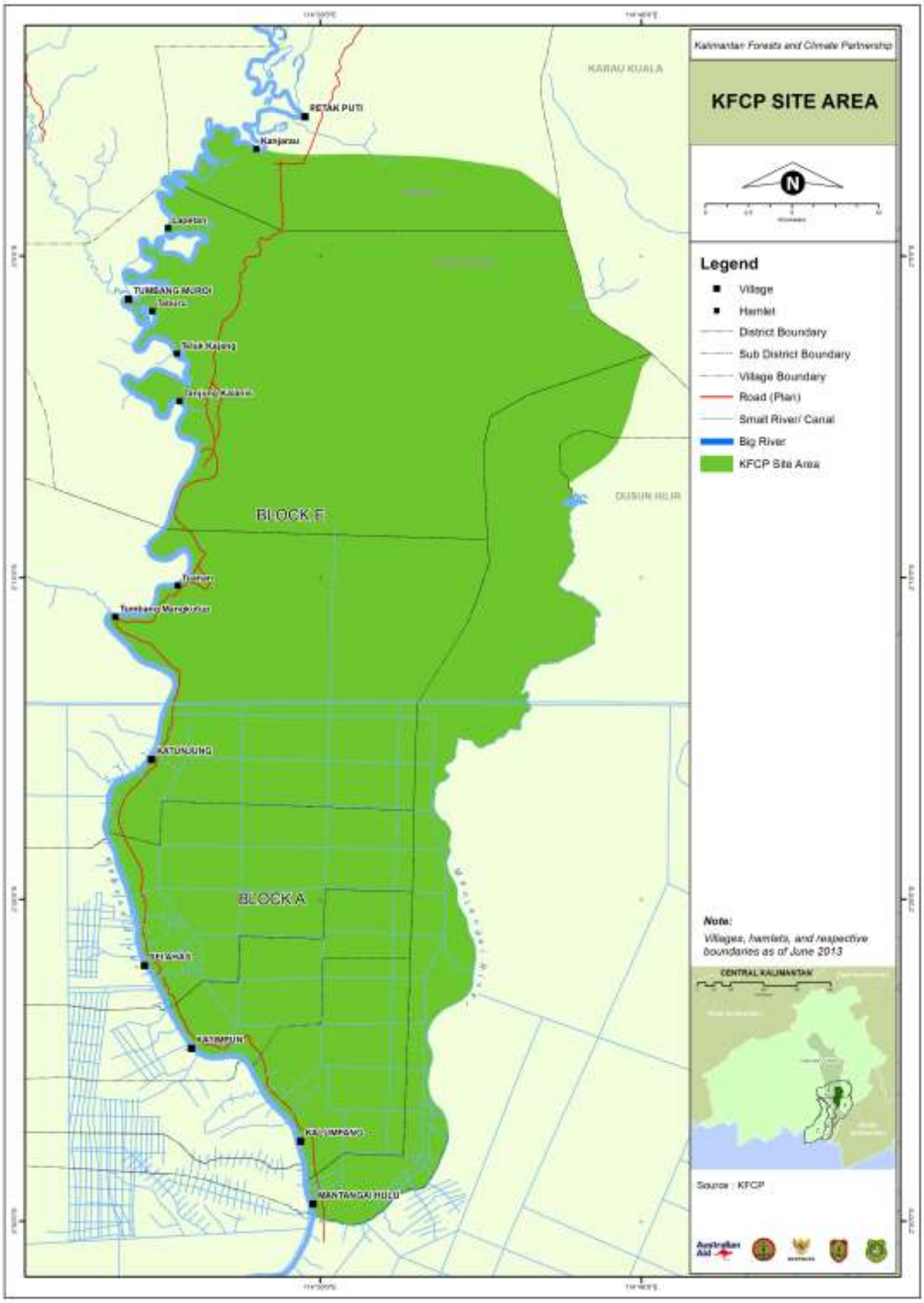
[1] ... and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

[2] During the monitoring study period (2010–2012) there were only seven governmentally-recognised villages made up from 14 hamlets. In July 2013 two of the villages were jurisdictionally split into two, resulting in nine villages.

activities under agreements between villages and the program (Village Agreements; VAs), fire management and monitoring, alternative livelihoods activities, and educational activities including workshops on fire management and farmer field schools, among others.

In order to be able to build a model for estimating greenhouse gas (GHG) emissions from tropical peatlands and, depending on the interventions implemented, to assess the effect of any physical interventions and social activities, KFCP required a core peatland monitoring unit to assess the changes in the local environment. This was also essential from the point of view of developing methodologies for calculating changes to rates of GHG emissions from tropical peat swamp forests (TPSF) where vast quantities of carbon are stored but where there are few developed practices for monitoring and calculating emissions from this ecosystem. To this end, KFCP established the Vegetation Monitoring team, the Fire Management team (FMTeam) and the Peat and Hydrology Monitoring team.

Figure 1.1: Map of KFCP area



Source: KFCP

Note: In July 2013 two of the 'jurisdictional villages' that bordered the KFCP area, Katunjung and Tumbang Muroi, split and became four villages, Tumbang Mangkutup and Katunjung, and, Tumbang Muroi and Lapetan, respectively. As the activities described in this report occurred when the villages had not yet split into four (2012), only seven villages are represented throughout this report.

1.2 KFCP's fire management strategy

Fire is one of the key risks to degraded peatlands. Research has already established the relationships between land clearing, drainage and altered rainfall patterns with fire events, frequency, and resulting GHG emissions. Fire on degraded peatlands is one of the primary causes of GHG release into the atmosphere, the other being microbial oxidation (peat decomposition). Fire itself leads to further peatland degradation, particularly in terms of the direction and speed of vegetation recovery. For REDD+ to be successful on tropical peatlands, effective strategies to reduce the incidence of fires are required.

To this end, KFCP explored and developed the key factors influencing fire management within the study area. It built a project-wide, and village-by-village specific, fire management strategy. The strategy incorporated not just response to occurrence of fires, but 'the five R's of fire management': Research, Risk assessment, Readiness, Response and Recovery (see Masal *et al*. 2014).

1.3 KFCP's fire management research

In addition to KFCP's fire management strategy, it was also essential to increase understanding of how fires occur on peatland, and what the results of those fires are. To address this, KFCP developed a research program implemented by the FMTeam to explore: what conditions led to peat fires, their frequency and distribution and how these are linked to land use and land management, and the risks of the fires developing into the more dangerous below-surface fires based on the distribution of HFL. The final component is addressed in this report, while the former components are addressed in the KFCP report 'Hotspot monitoring, fire investigation and types and distributions of assets in the KFCP area' (Graham *et al*. 2014).

1.4 Theory

One of the biggest barriers facing tropical peatland rehabilitation is fire (Page *et al.* 2009). Fires on peatlands are triggered by land use change, especially that which is linked with peat drainage (Page *et al.* 2009; Hooijer *et al.* 2006). Fires lead to further forest loss (Hoscilo *et al.* 2011), further complications of flooding (Wösten *et al.* 2006), human health problems due to smoke inhalation (Harrison *et al.* 2009), and the release of carbon (Page *et al.* 2002) and associated climate change (Hooijer *et al.* 2006). For peatland rehabilitation to be successful, and for carbon loss from the system to be reduced, fire management and prevention is essential (Page *et al.* 2009).

Across the peatlands of Kalimantan only 12% are recorded as intact TPSF (in a near-natural state) or slightly degraded, while the remainder show signs of degradation, disturbance, cultivation and drainage (Miettinen and Liew 2010), leaving them susceptible to fires (Hoscilo *et al.* 2011). The KFCP site is approximately 120 000 ha, with regular fires occurring in the southern section, which is estimated to be 50 000 ha. Given the extent of this problem, targeted and appropriate fire management is crucial (Masal *et al.* 2014; Page *et al.* 2009).

KFCP is working towards demonstrating activities that can reduce carbon loss from the degraded peatland system. Fires and fire management feature as an important part of those activities. Fires on peatlands can take two forms; they can burn *on the surface of the peat*, burning the surface grasses, ferns and shrubs, with the potential for some limited peat combustion at the surface, or the fire can burn *in the peat*, below the peat surface (Usup *et al.* 2004). The fires burning within the peat, as opposed to on the peat surface, result in greater carbon release (Usup *et al.* 2004). For more efficient and targeted fire management to lower carbon release levels, KFCP gave priority to targeting and suppressing the *peat fires* as opposed to the surface peat fires. Is it possible, therefore, to predict where peat fires will occur?

Based on research by Usup *et al.* (2004) it is understood that peat must reach a specific ignition temperature and moisture content before it burns. If this temperature/moisture content is not reached, the fire will pass over the surface, only burning the vegetation. It is likely that a HFL on the peat surface is one of the key factors that controls peat burning since it enables surface fires to burn long enough in one locality, by first drying the peat, by driving off moisture, and then raising the peat to its ignition temperature (de Mar and Moore 2009). Peat moisture content is also critical, with the likelihood of ignition increasing when the moisture content drops below 110% (Usup *et al.* 2004).

In tropical ecosystems, fuel load is linked to fire history. Healthy forest is slow to ignite as there is little ground fuel and the existing wood/forest is moist. However, when the first fire sweeps quickly through ground litter this damages and kills trees resulting in tree death, leading to a much higher density of ground fuel and making subsequent fires more severe. However, after several fires, fuel load lessens as fuel availability declines (Cochrane 2003; Cochrane and Barber 2009; Hoscilo *et al.* 2011).

1.5 Objectives

Based on the above theory and the literature on peat combustion, the preliminary step was to sample the KFCP for the presence, incidence and type(s) of heavy fuel. In the absence of specific fire data, it was not yet feasible to evaluate fires in peat in relation to HFL. This initial step was, therefore:

- To collect and analyse the HFL data (distribution, quantity and descriptive characteristics) in order to increase knowledge of HFL type across the KFCP area, and
- To evaluate HFL correlations with:
    - Fire history (specifically areas that had not suffered fires, suffered 1–2 fires, or suffered three of more fires), and
    - Land cover types

These correlations could then provide important information within a fire management strategy of potential high risk areas for peat fires.

2 METHODS

2.1 Study site

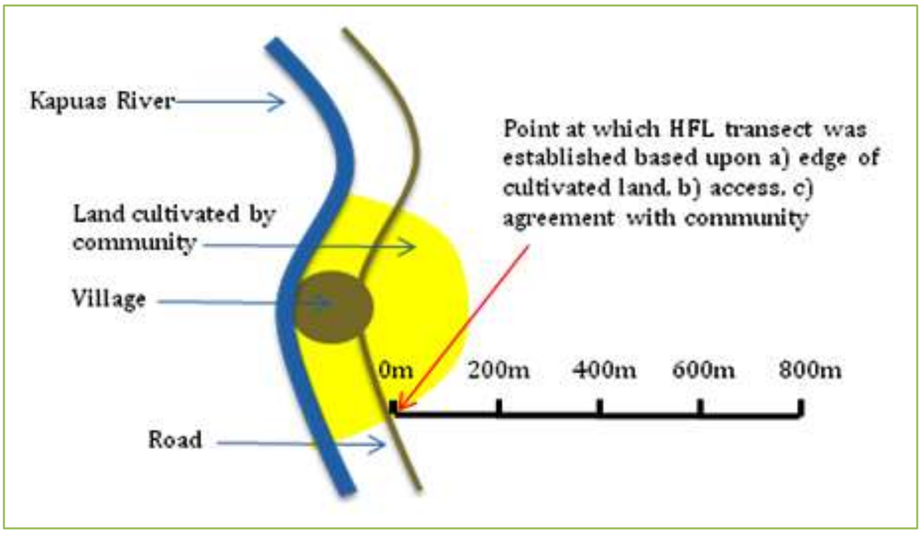
The KFCP site was located between the Kapuas and Mentangai Rivers, in the Kapuas district of Central Kalimantan, Indonesia. Fourteen small villages are located along the Kapuas River, which runs down the western side of the site (Figure 1.1). The area is PSF, disturbed through a system of canals and fires, resulting in much of the area now being covered by secondary forest, shrubs and ferns. Across this study site a transect system was established along which hydrological and peat data were recorded monthly, including the subsidence rate of the peat (Figure 2.2).

2.2 Locations

In order to address the objectives specified above (section 1.5), it was necessary to measure the HFL quantity and other descriptive characteristics (see section 2.3) across a range of locations in the KFCP area. The hydrology and peat transects were designed to cover the width and breadth of the KFCP area, and its prevailing environmental conditions and anthropogenic effects across the peat dome. Data was collected along these transects to assess the subsidence rate using subsidence poles located at set intervals along these transects (83 locations in total) (Figure 2.2). Assessing the HFL in the vicinity of these poles provided a good baseline of HFL data throughout the KFCP area. Furthermore, much other environmental data (on peat, hydrology and vegetation) was collected around this transect system, making future cross-analysis to other environmental factors possible.

To ensure coverage of a range of land cover types (and human activity, should future analysis require it) HFL was also assessed at each hamlet/village (14 in total) along the Kapuas River (Figure 1.1). Cultivated land surrounded each village. At a selected point along the boundary of cultivated land and the degraded PSF (selected based on access options, and through agreement with the village representatives), an 800 m transect was established running directly east into the KFCP area. Every 200 m along this transect, the HFL was measured, resulting in five HFL measurements for each village (70 in total) (Figure 2.1).

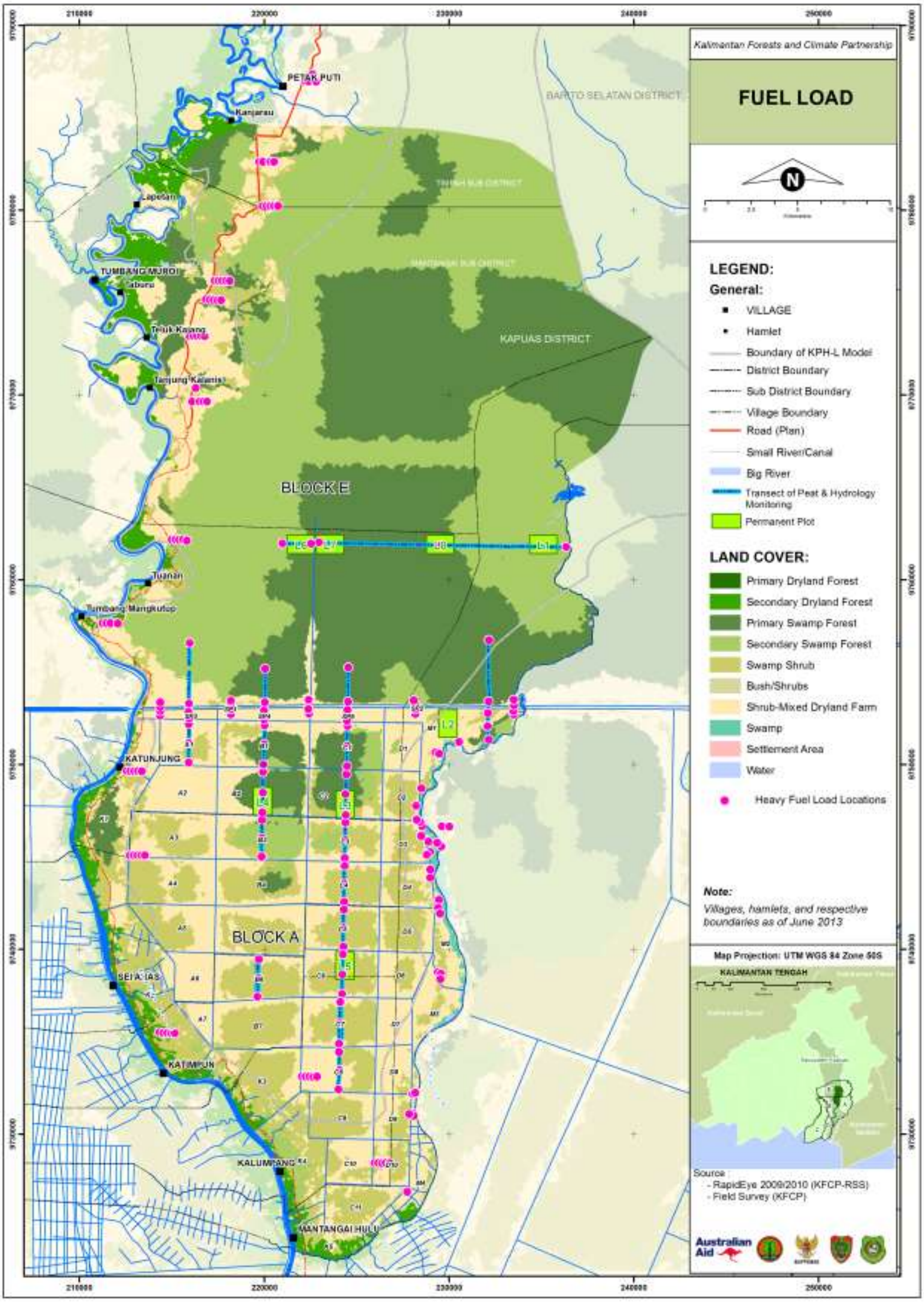
Figure 2.1: Illustrating transects established by the Fire Management team (FMTeam) to record five heavy fuel load (HFL) locations in the vicinity of each village



The range of fire histories were established, represented through the locations selected by using the above two techniques. It was found that the three or more fire history categories were under-represented, and so a field campaign was conducted to increase the HFL data for these fire history types (30 locations in total).

In total, HFL data were collected across a total of 183 locations (Figure 2.2), across several months in 2011.

Figure 2.2: Fuel load measurement locations



Source: KFCP

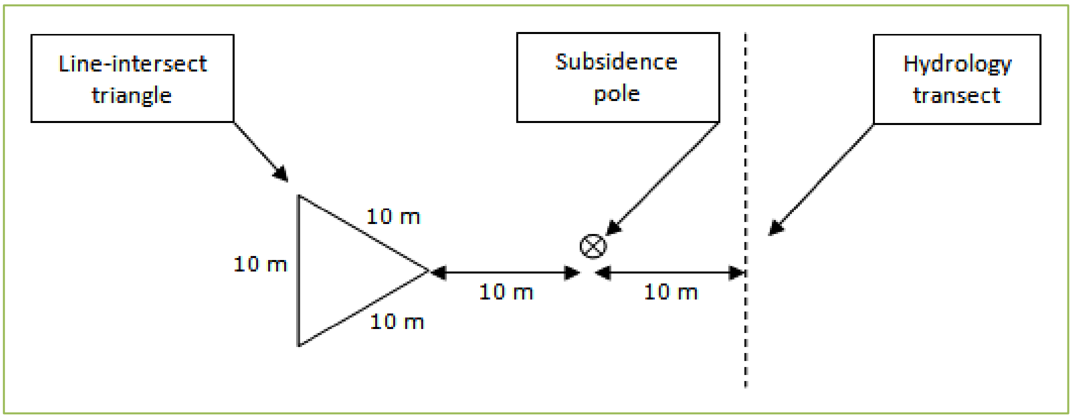
2.3 Heavy fuel load assessment methods

The quantity of the heavy fuel (wood material greater than 2.5 cm diameter) lying on or protruding from the peat at a variety of locations across the KFCP area were measured using the 'line intersect method' (van Wagner 1982). The section below describes the method used at the subsidence pole locations. This method for measuring HFL volume was used at all locations (those adjacent to subsidence poles, those in the vicinity of villages and those additional points to increase fire history coverage).

At every subsidence pole, 10 m behind the pole (away from the transect) a line-intersect triangle start point was established. If there was some obstruction or anomalous condition at any location, the line-intersect triangle was moved south to a suitable location—this new position was recorded on the relevant worksheet. The global positioning system (GPS) position at the start point of the triangle was recorded.

From this point a non-permanent triangle was set up (line-by-line) (Figure 2.3).

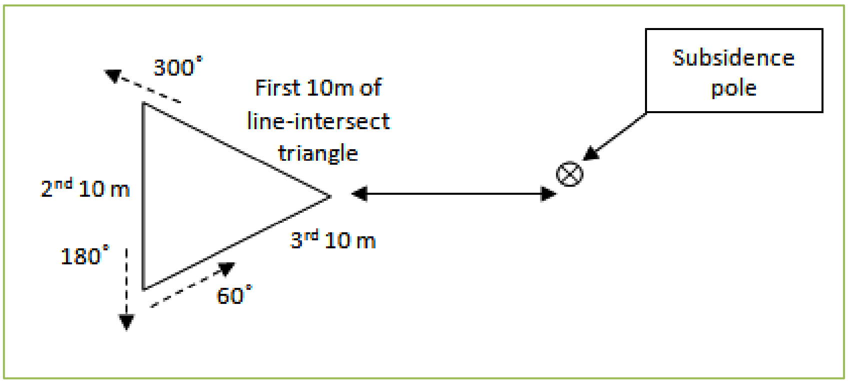
Figure 2.3: The layout and design of the line-intersect triangle in relation to a subsidence pole and hydrology transect



To measure the fuel load around the triangle, one team member held one end of a thin 10 m rope, while another team member walked at 300˚ until the rope was taut and held close to the ground. A third team member traversed the length of the rope, inspecting the ground. Any dead woody material that intersected the line and was greater than 2.5 cm in diameter was recorded. Other HFL characteristics were recorded, such as the source of the material (branch, log, root or stump), whether it emerged from the peat or was free-lying, the tree species (where possible) and evidence of burn scars. The final, fourth, member of the team recorded the findings.

Once the 10 m rope had been traversed, it was re-arranged to face south (180˚) from the far end position of the first rope placement, and the method repeated, and re-arranged again at the far end position of the second rope placement at 60˚ and the method repeated, bringing the measurers back to the start point with 30 m surveyed at three different angles (Figure 2.4).

Figure 2.4: The layout for the three angles and three sides of the triangle that made up a single line-intersect triangle used in analysis of HFL



2.4 Analysis

Once these data were collected, using the formulas provided in the 'Practical aspects of the line intersect method' (van Wagner 1982), the average diameter of fuel load for each line-intersect triangle and the volume of HFL for each area were calculated (Equation 1). These data have not presently been converted into biomass, as the mathematical constant required in the equation for dead wood density for PSF is lacking.

Eq.1. Volume (m^3/ha) = (Π^2/8*length of line) ∑diameter of fuel^2

Based on the GPS position of each HFL volume, the land cover (as assessed by Siegert *et al.* 2013) and fire history (number of burns) data for each location—data already held in KFCP's geographic information system (GIS) database—were also collated. Note: land cover data was collected in 2010, HFL data was collected in 2011 before the dry season, therefore it is unlikely any fires occurred between land cover data collection and HFL data collection. The mean HFL volume and standard deviation were calculated in relation to fire history category (0x, 1x, 2x, 3x, 3+x burned) and also for land classification category (in the KFCP area these categories largely included Primary Swamp Forest, Secondary Swamp Forest, Mixed Shrub/Grassland, Swamp, Swamp Shrub[3]—see Figure 2.2, for graphical representation). The relationship between HFL volume and fire history and HFL volume and land cover type were analysed statistically using ANOVA (ANalysis Of VAriance). Data were checked as to whether it was normally distributed and homogenous. In all cases the HFL data was found not to be homogenous and so the Mann-Whitney U (MWU) test was used.

[3] This land cover classification is explained in Siegert *et al*. (2013), and is based upon the land cover classifications and maps that conform with both the Indonesian Ministry of Forestry (MoFOR) and Presidential Working Unit for the Monitoring and Control of Development (*Unit Kerja Presiden Bidang Pengawasan dan Pengendalian Pembangunan;* UKP4) approaches.

3 RESULTS AND DISCUSSION

3.1 Relationship between HFL and fire history

There was sufficient replication of the HFL data collection locations in relation to fire history (Table 3.1).

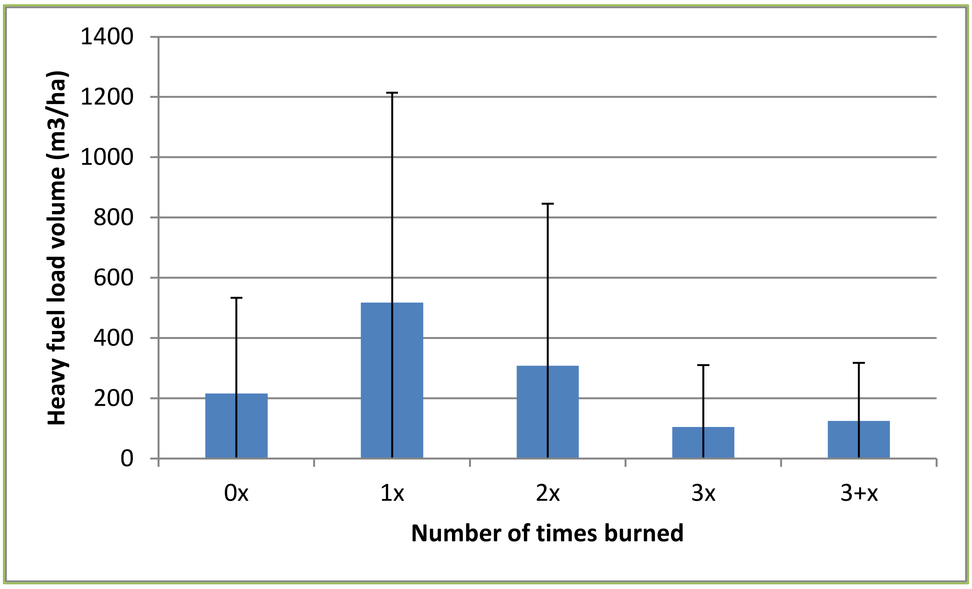
Table 3.1: Number of heavy fuel load (HFL) data collection points for each fire history category

Number of burns (fire history)	Number of HFL data collection points
0x	41
1x	41
2x	48
3x	35
3+x	17[a]

[a] A single large anomalous data point was removed for analysis (initial total = 18)

The average HFL volumes found at the 1x, 2x, 3x and 3+x burn locations did follow the pattern suggested by the literature (Figure 3.1). Locations that had burned once or twice had a higher, on average, HFL volume as compared to the locations that had not burned. The locations that had burned three or more times had lower HFL volumes. For locations that had not burned, analysis was carried out to explore the effect of logging (logged *vs*. not logged), but this analysis showed no significant difference between these two categories, so these data remained grouped. For all fire histories, the standard deviations for HFL volumes were large, with several locations in each fire history class having very low or zero HFL. Consequently variation and degree of overlap between the data in each category was high (Figure 3.1).

Figure 3.1: The HFL volume average and standard deviation for each fire history category



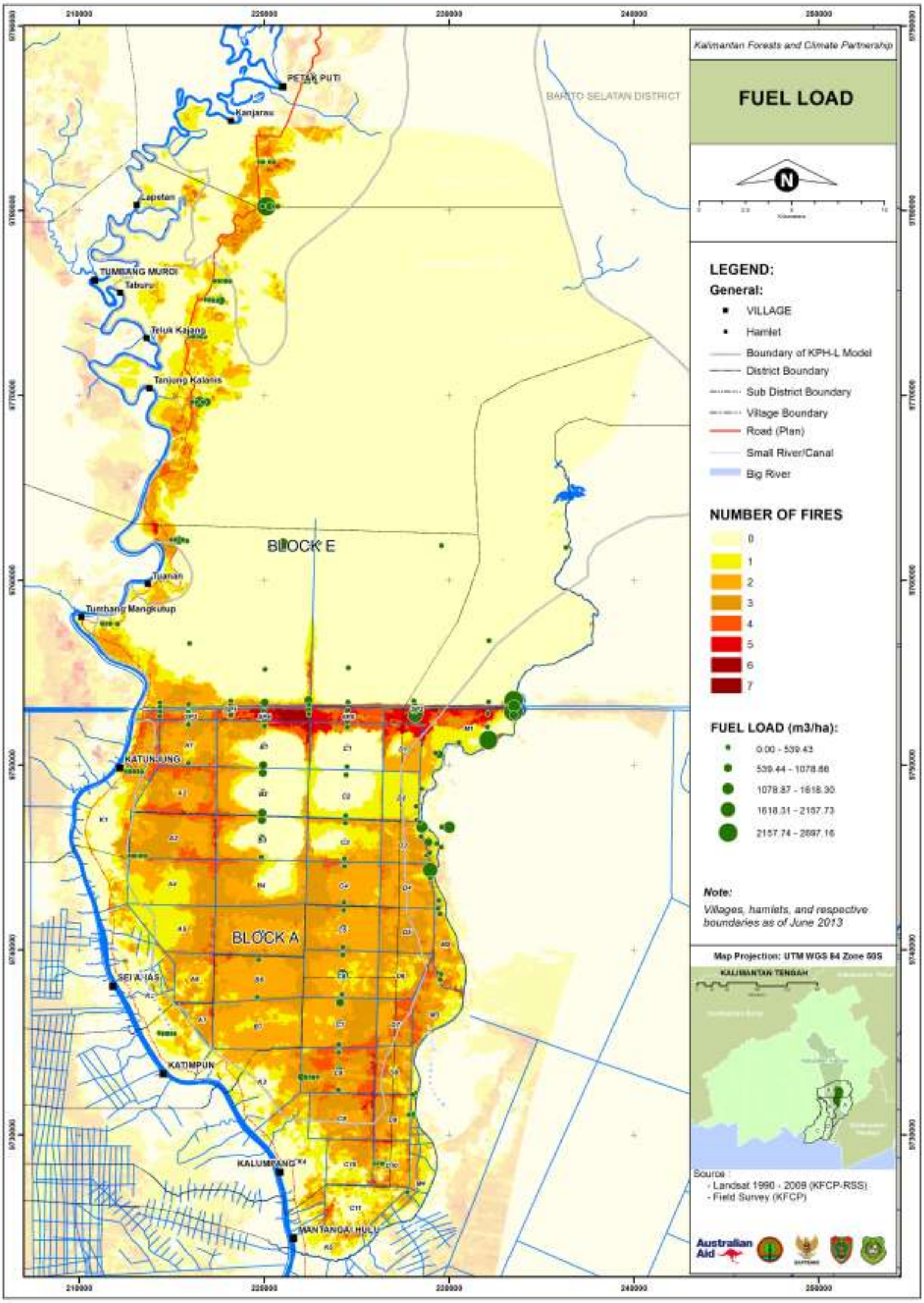
Despite the large variation within each category, and degree of overlap across categories, it was still found that there was a statistical significance when comparing the HFL volume between 0x–3x burn locations to 0x–3+x burn locations (with 0x burn taken as the 'control' or baseline category). Furthermore, when considering the difference, or change, to the HFL after each successfive fire, it was shown that although HFL increased from 0x to 1x burns, this was not significant. However, 1x burn did have a significantly greater average HFL volume as compared to 2x burn and, similarly, 2x burn had a significantly greater average HFL volume compared to 3x burn. There was no significant difference for 3x and 3+x burns (Table 3.2). A GIS map was created to show the HFL volumes and the fire history across the KFCP area (Figure 3.2).

Table 3.2: The p-values attained in the Mann-Whitney U test in comparing the heavy fuel load (HFL) volumes as found in the 0x burn locations to other fire history categories

Number of fires (comparison)	p-value	Comments
0x–1x	0.131	Not statistically different
0x–2x	0.443	Not statistically different
0x–3x	0.004**	Significantly different, with the 0x burn locations having a greater HFL than the 3x burn locations
0x–3+x	0.061*	Significantly different, with the 0x burn locations having a greater HFL than the 3+x burn locations
1x–2x	0.014**	Significantly different, with the 1x burn locations having a greater HFL than the 2x burn locations
2x–3x	0.010**	Significantly different, with the 2x burn locations having a greater HFL than the 3x burn locations
3x–3+x	0.282	Not statistically different

* - significant, ** - highly significant

Figure 3.2: A GIS map of the KFCP area depicting fire history across the area (background) and the volumes of fuel load at each recorded location (green circles)



Source: KFCP

3.2 Relationship between HFL and land cover classification

There was sufficient replication of the HFL data collection locations in relation to three of the land cover classifications. However, 'Swamp' had only 6 data collection locations and 'Secondary Swamp Forest' had only 11. While analysis was possible for these two land cover types, it would be advantageous to collect more data before further analysis is undertaken (Table 3.3).

Table 3.3: Number of heavy fuel load (HFL) data collection points for each land cover classification type

Forest type	Number of HFL data collection points
Primary Swamp Forest	18
Secondary Swamp Forest	11
Mixed Shrub/Grassland	100
Swamp	6
Swamp Shrub	48

When considering the HFL volumes found for each land cover classification, based on the average data (Table 3.4), all HFLs were similar in volume, apart from 'Swamp' land cover, which was significantly higher (Figure 3.3). Furthermore, as observed for the fire histories, the standard deviations for the HFL volume data were large, with several locations in each land classification having very low or zero HFL. Consequently, variation and degree of overlap between each category was high (Figure 3.3). A GIS map was created to show the HFL volumes and the land cover types across the KFCP area (Figure 3.4).

Figure 3.3: The heavy fuel load (HFL) volume average and standard deviation for each land cover classification

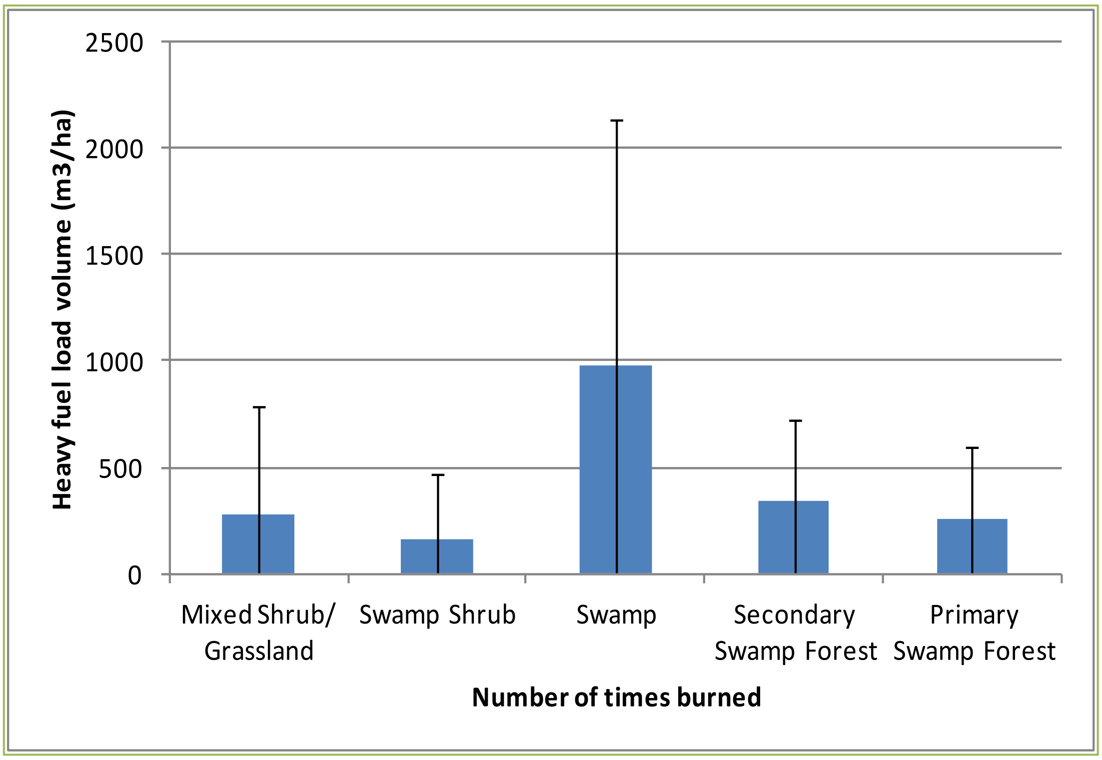
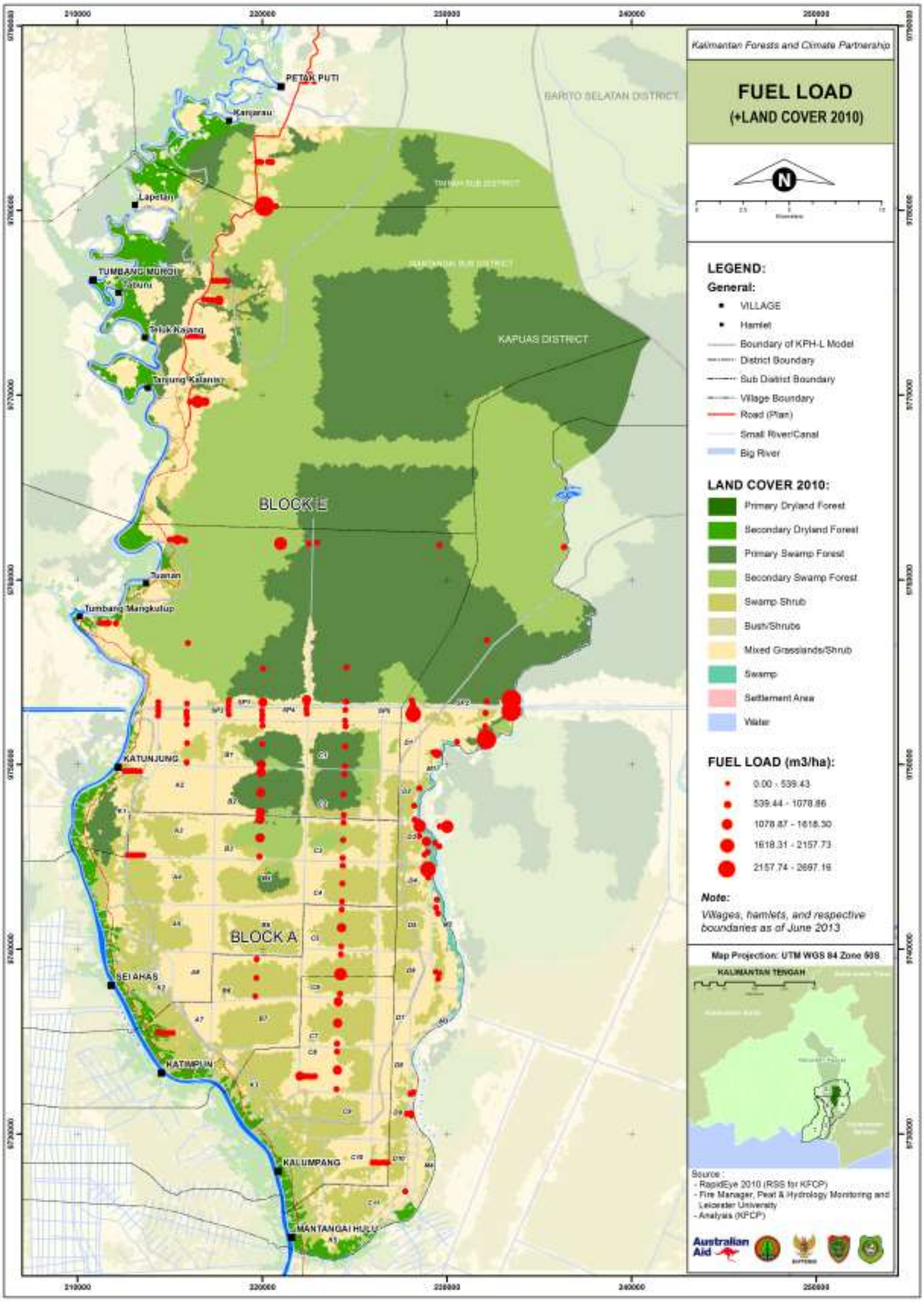


Table 3.4: The p-values attained through the Mann-Whitney U test in comparing the heavy fuel load (HFL) volumes as found in the 'Primary Swamp Forest' to the other land cover classifications

Land cover classifications (comparison)	p-value	Comments
Primary–Secondary	0.298	Not statistically different
Primary–Mixed Shrub/Grassland	0.572	Not statistically different
Primary–Swamp	0.011*	Significantly different from the 'Swamp' land cover locations having a greater HFL than the 'Primary Swamp Forest' locations
Primary–Swamp Shrub	0.253	Not statistically different

* - significant

Figure 3.4: A GIS map of the KFCP area depicting land cover categories across the area (background) and the volumes of fuel load at each recorded location (red circles)



N.B. 'Swamp' covers a small percentage of the KFCP area and is primarily found along the Mantangai River.

Source: KFCP

The current data set also recorded other characteristics of the HFL, aside from volume: wood type (root, trunk, branch, etc.), whether the wood was lying on the surface or penetrating the peat, the species of the wood, and whether the wood showed burn marks. Aspects of HFL location were also recorded: proximity to village and canal, land management and vegetation cover. Further analysis could be carried out on these data based on these criteria, and may be relevant in explaining the large variation within each fire history category and land cover category.

These data could also be used for biomass calculations as a 'dead wood' component of aboveground biomass. However, to use the data to calculate aboveground dead wood biomass, further research would be required to determine the wood density mathematical constant needed in calculations from volumes to biomass.

4 IMPLICATIONS FOR FIRE MANAGEMENT AND FUTURE ACTIONS

The data presented within this report follow the trend described in the literature for other ecosystems; that after 1–2 fire events, HFL increases in volume as compared to an area with no fire history. Subsequently three or more fires result in the average HFL volume significantly decreasing in comparison to non-burned areas. After one fire event, the HFL significantly decreases for each subsequent fire event, until more than three fire events have occurred. Furthermore, in a comparison between land cover and HFL (where land cover is understood to also be linked to fire history [Hoscilo *et al.* 2011]), certain land cover types were shown to be linked to high HFL volumes, notably 'Swamp' land cover. Consequently, HFL volumes appear to be linked to both fire history and land cover classification.

Variation within each fire history and land cover category is, however, large, with numerous low HFL volumes for all categories. This requires further explanation. As noted above, this might be explained with further analysis of HFL characteristics, for example, whether the HFL is free-lying or penetrating the peat may be important. A second important contributing factor to this variation may be the year when fires occurred. The main fire events in this region occurred in 1997, 2002 and 2006; several years before KFCP began. While this report has explored HFL relationship with fire events and land cover, it is important to appreciate that these major fire events and the immediate subsequent HFL effects are missing. This 'age of the HFL data' factor may account for the large variation and, specifically, may account for the large number of low or zero HFL volume points found within each 'number of fire events' class.

This initial study aimed to attain HFL data (distribution, quantity and characteristics) across the KFCP area, and explore the relationship of these data to fire history and land cover. This study has met these objectives, and early results indicate useful application may be possible. These data might be used to help target high-risk areas for developing below-surface peat fires and, equally, lower risk areas might be de-prioritised in fire management strategies. This work should be treated as an initial study only; the data are not conclusive. The wide variation within each category needs to be further accounted for, and the 'age of the HFL data' must be considered. Equally, other key questions not addressed in this study need to be further explored, such as whether and how HFL actually increases the risk of below-peat fires.

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