

## A preliminary assessment of the distribution of vegetation fires in Myanmar and key drivers

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**Abstract:** Haze pollution from vegetation fires in the ASEAN region is a recurrent issue. Due to this problem, in 2002, ASEAN countries gathered efforts to tackle vegetation fires and reduce haze pollution in the region. In the case of Myanmar, vegetation fires remain to be assessed. This study aimed at investigating the spatio-temporal distribution of vegetation fires in Myanmar based on active fire data from MODIS. The results showed that 811,143 fire hotspots (FHS) were detected by MODIS over the period 2006-2017 with on average 68,000 FHS each year. Most of the FHS were found to occur on forest land, followed by other wooded land and crop land. Based on the distribution of FHS in Myanmar, a number of States and Regions were selected as priority areas for vegetation fires control to identify the main drivers. Through expert judgement by representatives from government organisations, it was found that the main drivers of vegetation fires in Myanmar include, in decreasing order of importance, burning for land clearance; burning for collection of wood and non-wood forest products; careless and accidental fires; burning for hunting; and burning for the removal of agricultural residues.

**Keywords:** Fire Hotspots, MODIS Data, Land Cover Type, Vegetation Fires drivers, Myanmar.

### 1. Introduction

Fire is usually used as a land clearance tool in the Southeast Asian (SEA) region [1]. Vegetation fires can be wildfire incidents or prescribed burning operations that use vegetation as fuel [2]. Vegetation fires are one of the major sources of air pollutant emissions in SEA [3]. Emissions from vegetation fires are an important topic in the region in terms of air quality, global atmospheric chemistry, climate change and haze pollution [4]. In Myanmar, vegetation fires involve mainly the open burning of forest biomass and agricultural residues. The nature of fires and their spatiotemporal distribution are very important to assess their impacts on the environment [1].

The ASEAN Specialized Meteorological Center (ASMC) is the main focal center for vegetation fires and the haze pollution database in the ASEAN region. Information on fire hotspots (FHS) from the ASMC website shows that Myanmar is the largest contributor to vegetation fires in the northern ASEAN region [5]. Among ASEAN countries, Myanmar is also the least studied country with regard to vegetation fires. This is due to poor data availability because of insufficient capacity and technical knowledge [1].

The literature review suggests that the Moderate Resolution Imaging Spectroradiometer (MODIS) is better suited to assess fire detection than the National Oceanic and Atmospheric Administration (NOAA). The NOAA sensor (AVHRR) has indeed been mainly designed for weather surveillance and sea surface temperature management, and so contains some weaknesses with regard to fire detection [6]. To characterize fires in this study, fire occurrence data from MODIS was used as it is suitable for fire detection applications [7]. The MODIS active fire data (MCD14ML) provides continuous, well-calibrated and relatively long-term global records of daily fire occurrence [8].

In this study, therefore, MODIS data collected from the Fire Information for Resource Management System (FIRMS)

was used to investigate over the period 2006-2017, the temporal distribution of vegetation fires in Myanmar and the main land use types subject to fire based on the spatial distribution of FHS. Based on the distribution of FHS, key States and Regions were selected to identify the main drivers of vegetation fires based on expert judgement.

### 2. Material and methods

#### 2.1 Satellite data, land cover and data processing

In this study, MODIS monthly active fire standard data product (MCD14ML) for the period 2006-2017 was collected and used. The data is provided by FIRMS and is a subset of the standard quality data already processed by the MODIS Fire Team and Computing Facility at the University of Maryland [8]. In relation to land cover, this study used the national land use map provided by the Myanmar Forest Department [9] based on 2010 data and the Myanmar administrative boundary map produced by the Myanmar Information Management Unit [10]. This land cover map has a 30 m spatial resolution and includes 10 land cover classes including, closed forest, open forest, mangrove forest, other wooded land, cropland, other land, settlements, wetland, grassland and water. Canopy cover greater than 40% refers to closed forest, 10 to 40% to open forest and 5 to 10% to other wooded land. Other land includes meadows and pastures, built up areas, and barren land. On a percentage basis of the total land cover, forest represents 44%, other wooded land 28 %, crop land 24% and other land 4% [9]. To evaluate the spatio-temporal distribution of FHS, active fire data from MODIS were overlaid with the land use map of Myanmar to classify them accordingly. Data processing was performed using data management and analysis tools and techniques available within the GIS software QGIS 2.18.15 version.

To characterize the temporal extent of FHS, this study assessed the total and mean fire counts on a monthly and yearly basis over the period 2006-2017. To study the influence of FHS based on land cover type, the dominant land cover class for each fire hotspot was extracted. To assess the percentage of FHS belonging to each land cover class as well as the percentage of hotspots belonging to each state and region of Myanmar, equation (1) was used based on Biwas et al. [1]:

$$\% \text{ of hotspots} = \frac{\text{Number of hotspots in a particular land cover class}}{\text{Total number of hotspots}} \times 100 \quad (1)$$

## 2.2 Priority areas and expert judgement

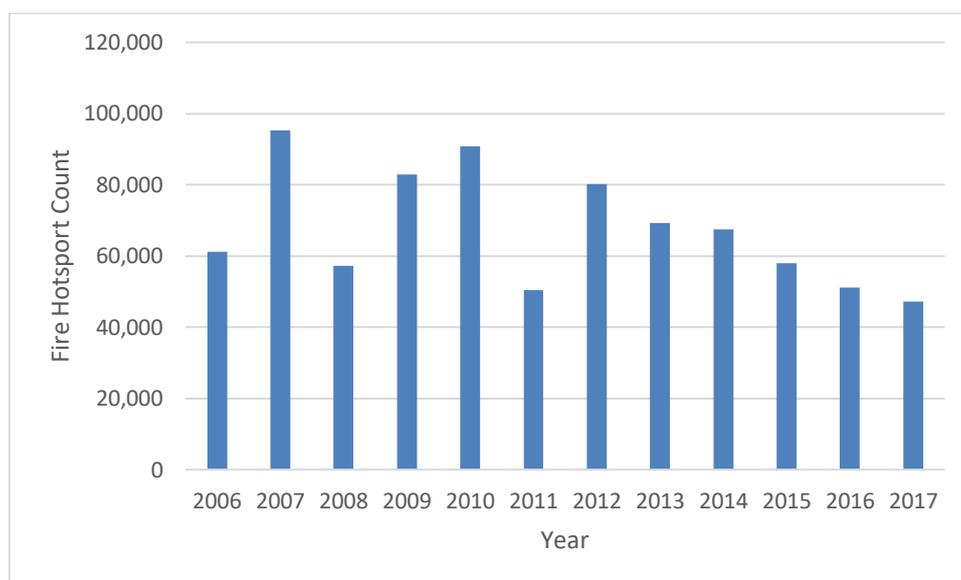
Based on the distribution of FHS in Myanmar, States and Regions where vegetation fires appear to dominate were identified. On that basis, qualitative research was performed to assess the main drivers of vegetation fires in the country. This was implemented via online interviews with experts who are responsible for vegetation fires control in the country. The participants were selected from the departments in charge of dealing with vegetation fires and control including, the Environmental Conservation Department, the Forest Department and the Department of Agriculture. A total of 21 participants were selected based on

the above three related departments in the States and Regions focused on in this study. Unstructured and semi-structured interviews were implemented to investigate the major drivers of vegetation fires in Myanmar.

## 3. Results and Discussion

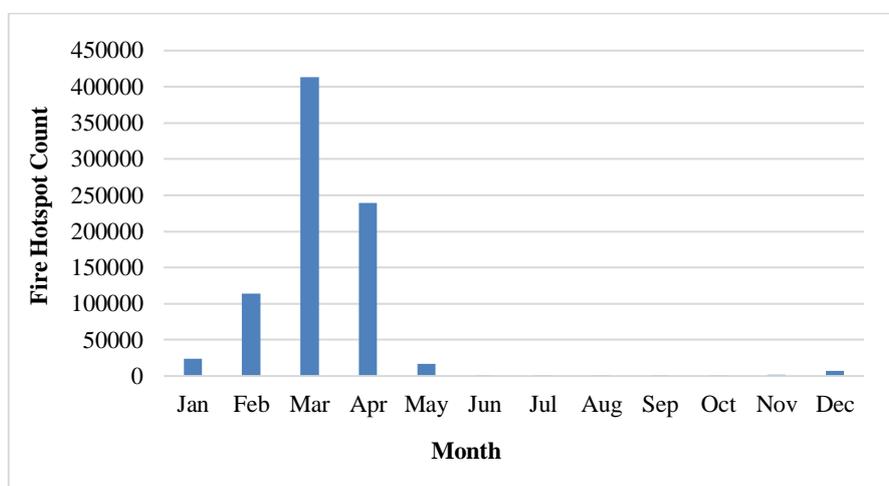
### 3.1 Temporal distribution of FHS in Myanmar

As shown in Figure 1, the cumulative number of FHS over the period 2006-2017 amounts to 811,143. The highest number of FHS occurred in 2007 with 95,260 counts and the lowest in 2017 with 47,169 counts. The annual average fire count is 67,959. On that basis, as illustrated in Figure 2, approximately 99% of the fires were observed to occur during the dry season (from January to May). March and April are the months where the number of FHS culminates with nearly 80% of the total number of FHS recorded during that time each year. These are the hottest months of the year and a time during which the amount of biomass in forested areas is the highest as trees shed their leaves during that time [11]. Also, it is a period during which crop harvesting takes place, including land clearance and preparation for subsequent cycles of production [12].



**Figure 1.** Annual FHS distribution in Myanmar based on MODIS data during 2006-2017.

Note: MODIS data collected from FIRMS [8]



**Figure 2.** Average monthly FHS distribution in Myanmar based on MODIS data (2006-2017).

Note: Based on MODIS data from FIRMS [8]

### 3.2 Spatial distribution of FHS based on land cover types in Myanmar

As shown in Table 1, over the period 2006-2017, about 46% of the annual average number of FHS occurred on forest land (31,315 km<sup>2</sup>), followed by 37% on other wooded land (25,157 km<sup>2</sup>), 16% on cropland (10,658 km<sup>2</sup>) and 1% on other land (466 km<sup>2</sup>). The cumulative burned area was found to amount to 375,777 km<sup>2</sup> on forest land, 301,887 km<sup>2</sup> on other wooded land, 127,890 km<sup>2</sup> on crop land and 5,589 km<sup>2</sup> on other land.

Looking at the annual distribution of FHS based on land cover types, the data in Table 1 shows that the highest number of FHS for all land cover types occurred in 2007 and the lowest in 2017. In 2007, about 50% of the total number of fires was detected on forest land, followed by other wooded land with 35%, cropland with 14% and other land with 1%. Compared to 2007, the number of FHS in 2017 was 62% lower on forest land, 44% higher on other wooded land and 28% higher on crop land. These results may be explained in part by the practice of shifting cultivation followed by farmers, which encroach on forest areas,

and by the control measures set in place at the national level to prevent illegal logging as well as the banning of timber export [13].

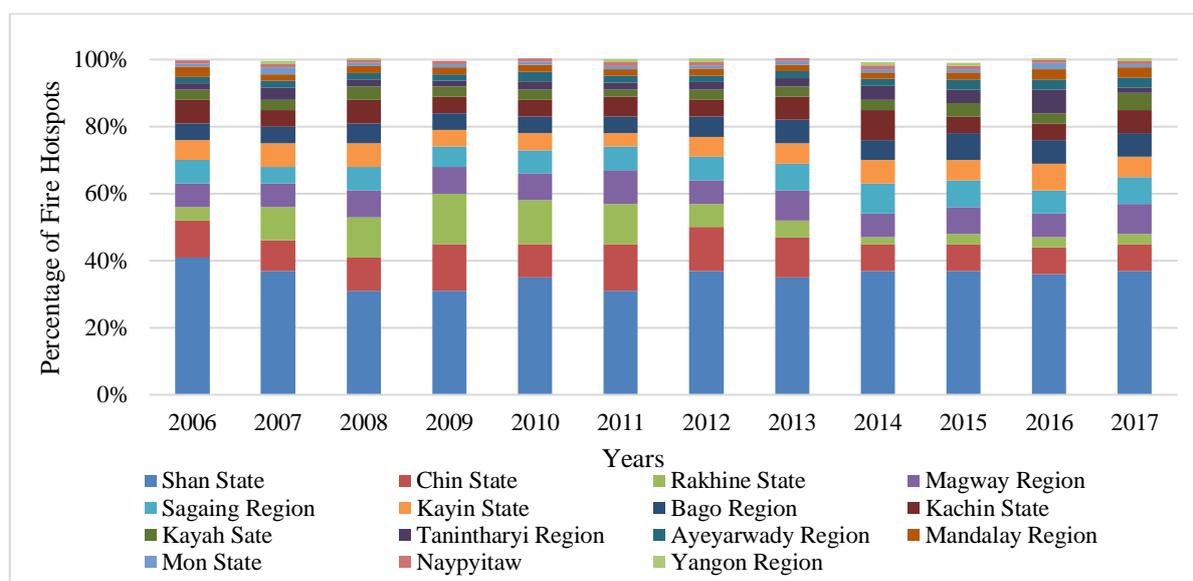
### 3.3 Spatial distribution of FHS over States and Regions of Myanmar

The general spatial distribution of fires is observed to dominate in inland areas of Myanmar (rather than in coastal areas and the delta region). As illustrated in Figures 3 and 4, the largest share of FHS is observed in the Shan State which is located in the eastern part of the country, representing on average 35% of the total number of FHS over the period 2006-2017. This is followed by the Chin State in the upper western part of Myanmar with 10%, and the Magway Region in the central area of Myanmar and the Rakhine State in the lower western part of the country with 8% each. The FHS are observed to dominate in the Shan State for the whole study period while the situation of FHS is observed to vary in other States and Regions.

**Table 1.** FHS distribution based on land cover in Myanmar (2006- 2017).

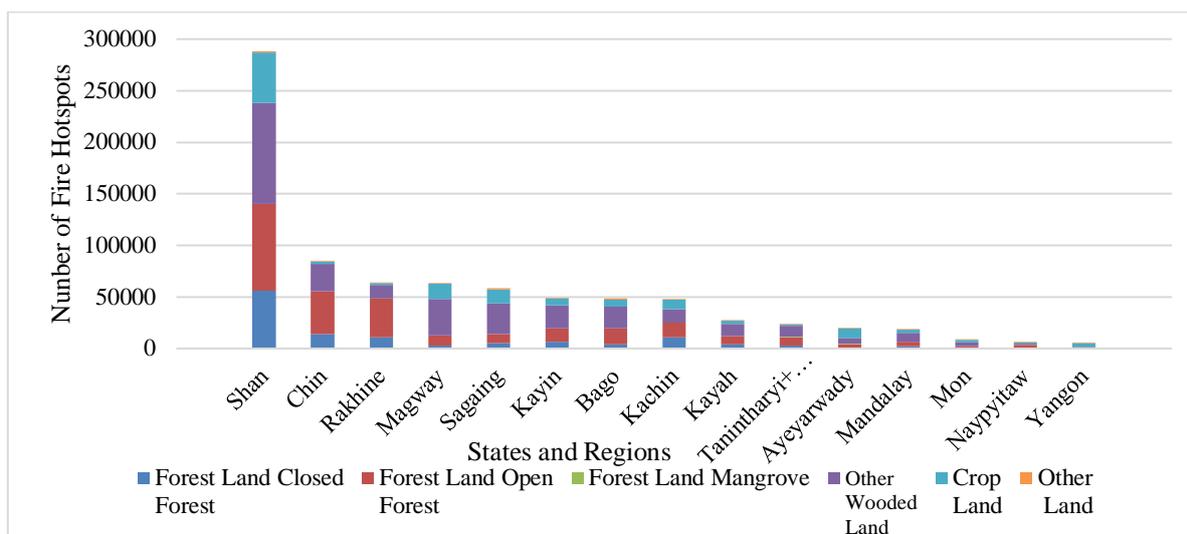
Hotspot Counts (Years)	Forest Land			Other Wooded Land	Crop Land	Other Land	Total
	Closed Forest	Open Forest	Mangrove				
2006	9,286	17,586	67	23,924	9,889	430	<b>61,182</b>
2007	15,291	31,867	99	33,607	13,811	585	<b>95,260</b>
2008	8,478	18,656	48	21,040	8,659	401	<b>57,282</b>
2009	12,794	29,956	53	28,185	11,387	540	<b>82,915</b>
2010	15,081	30,673	88	31,438	12,895	579	<b>90,754</b>
2011	6,497	16,527	34	19,019	8,092	329	<b>50,498</b>
2012	13,168	25,953	69	29,094	11,338	505	<b>80,127</b>
2013	10,456	20,961	56	26,686	10,633	461	<b>69,253</b>
2014	9,905	18,575	86	26,831	11,552	584	<b>67,533</b>
2015	7,869	14,718	47	23,948	10,984	457	<b>58,023</b>
2016	7,851	14,853	44	19,402	8,638	359	<b>51,147</b>
2017	6,298	11,761	26	18,713	10,012	359	<b>47,169</b>
<b>Annual Average</b>	<b>10,248</b>	<b>21,007</b>	<b>60</b>	<b>25,157</b>	<b>10,658</b>	<b>466</b>	<b>67,595</b>

Note: Based on MODIS data from FIRMS [8]



**Figure 3.** Annual percentage distribution of FHS in Myanmar by States and Regions (2006-2017).

Note: Based on MODIS data from FIRMS [8]



**Figure 4.** FHS distribution based on land cover in States and Regions of Myanmar (2006-2017).  
 Note: Based on MODIS data from FIRMS [8]

FHS were mostly found to occur in States rather than Regions of Myanmar. On average, about 70% of the FHS are located in States. Based on land cover type, approximately 81% of the FHS on forest land are located in States (84% in closed forest, 79% in open forest and 27% in mangrove forest), followed by 63% on other wooded land, 58% on crop land and 48% on other land. This observation can be explained by the differences in slope and elevation between States and Regions, and land cover. All States in Myanmar are located in hilly regions and covered mainly by forest, followed by other wooded land while all Regions in Myanmar are located in central plain areas, coastal areas and the delta region.

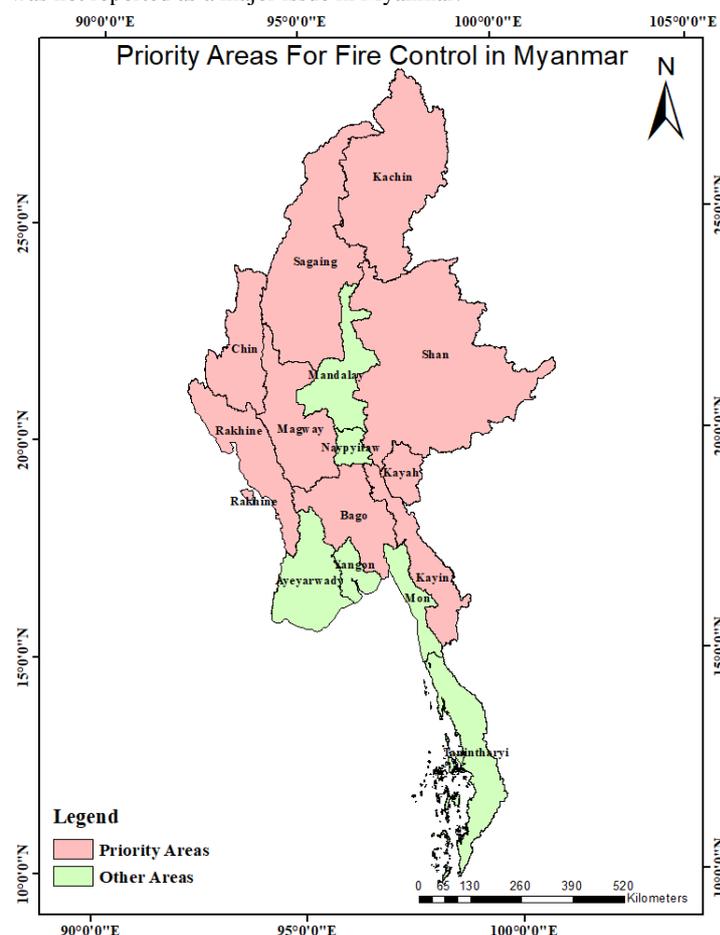
**3.4 Priority areas for vegetation fires control**

Based on the distribution of FHS in Myanmar (see Figure 4), 9 States and Regions were identified as potential priority areas for vegetation fires control. These include: Shan, Chin, Sagaing, Rakhine, Magway, Kachin, Bago, Kayah and Kayin. Their locations are illustrated in Figure 5. They represent about 80% of the total land area of the country, comprising 85% of forest land, 83% of other wooded land, 69% of crop land and 57% of other land. About 90% of the FHS detected in Myanmar fall in these areas, including, 92% on forest land, 90% on other wooded land, 84% on crop land and 80% on other land. Based on land use types, focusing on forest land, the States and Regions of Shan, Chin, Rakhine, Kachin and Magway constitute priority areas to control fires. For other wooded land, the States and Regions of Shan, Chin, Sagaing, Magway and Kayin are priority areas. For crop land, the States and Regions of Shan, Sagaing, Magway, Chin and Kayah are the main priority areas for vegetation fires control.

**3.5 Main drivers of vegetation fires based on expert judgement**

To investigate the main drivers of vegetation fires in Myanmar, representatives from government organisations in the country were interviewed. These representatives are involved in vegetation fire control activities and are from 3 main organisations that are the Environmental Conservation Department, the Forest Department and the Department of Agriculture. From the nine priority areas pre-selected, representatives from the above organisations are located in seven States and Regions. These are Shan, Chin, Rakhine, Kayin, Kayah, Magway and Bago. Therefore the scope of the investigations focused onto these 7 States and Regions.

Based on the expert interviews, it was found that the main drivers of vegetation fires in Myanmar include in decreasing order of importance: (1) burning for land clearance (agricultural expansion, shifting cultivation practices, plantations, urban development, fire prevention in forested areas and grazing), (2) burning for collection of wood and non-wood forest products, (3) careless and accidental fires (camping, logging and illegal logging), (4) burning for hunting and (5) burning for the removal of agricultural residues. Fire due to prolonged drought was not reported as a major issue in Myanmar.



**Figure 5.** Priority areas for vegetation fires control in Myanmar.

Based on the FHS data and the expert interview results, a number of main drivers of vegetation fires were identified for each of the priority areas considered for fire control. In the case of forest fire, the States and Regions of Shan, Chin, Rakhine, Kachin and Magway were identified as the priority areas for fire control and the main drivers identified to include: (1) burning for land clearance (mainly for plantations, shifting cultivation practices, and fire prevention in forest areas), (2) burning for collection of wood and non-wood forest products (3) burning for hunting, and (4) careless and accidental fires. For fire occurring on other wooded land, the States and Regions of Shan, Chin, Sagaing, Magway and Kayin were identified as the priority areas for fire control and the main drivers identified to include: (1) burning for land clearance (mainly for agricultural expansion, shifting cultivation practices and grazing), (2) careless and accidental fires (smoking and cooking), (3) burning for hunting, (4) burning for collection of wood and non-wood forest products and (5) burning for the removal of agricultural residues. For crop land, the States and Regions of Shan, Sagaing, Magway, Chin and Kayah were identified as the key areas for fire control and the main drivers to include: (1) agricultural residues burning, (2) land clearance and preparation for crops cultivation, and (3) shifting cultivation practices.

#### 4. Conclusion

From the investigations of this study it was found that the highest number of FHS occurred in 2007 and the lowest in 2017. The largest number of FHS was found to occur each year during the dry season, peaking in March and April and accounting for more than 80% of the total number of FHS detected each year. Most of the FHS were found to occur on forest land (46%), followed by other wooded land (37%), crop land (16%), and other land (1%). Potential contributing factors to the continuous decrease in FHS observed over the past 5 years of the period studied were reported to include control measures to prevent illegal logging in the country and the banning of timber export. From the distribution of FHS in Myanmar, it was found that most of the FHS occurs in inland areas and that most are located in States (about 70% on average). From the 7 States and Regions selected as potential priority areas for fire control (Shan, Chin, Rakhine, Kayin, Kayah, Magway and Bago), the main drivers of vegetation fires were investigated based on expert judgement. The results showed that the main causes include burning for land clearance, burning for collection of wood and non-wood forest products, careless and accidental fires, burning for hunting, and burning for the removal of agricultural residues.

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