Peat subsidence in a tropical rubber plantation during a strong El Niño year

Nur Wakhid*
Indonesian Swampland Agriculture Research Institute

Abstract. El Niño usually induces peat fires because dry season was prolonged and rainfall was low. This event potentially increases soil CO2 emissions and peat subsidence on tropical peat due to low groundwater level. Despite this, El Niño impacts on peat soil subsidence is understudied in Indonesia. To fill the gap, we measured peat surface elevation to determine peat soil subsidence at monthly basis during dry season, from June to November, in the strong El Niño year of 2015 and the normal year of 2014. A rubber plantation cultivated on peat soil was selected as a representative area for this research. Subsidence (in cm) was determined by calculating the difference in ground elevation between June and November for 2014 and 2015. Measurement was done by inserting three steel pipes vertically until underlying mineral substrate. We found that peat soil subsidence in strong El Niño year was larger than that of normal year. This finding can be further exploited as the baseline information for peatland management under climate change and or in extreme weather.

1. Introduction
Tropical peatland is one important ecosystems in the global carbon (C) budget because it stores a huge amount of C in their belowground. This ecosystem was estimated to store up to 104.7 Pg C including a newly peatland found in Congo Basin [1]. In Southeast Asia, Indonesia becomes the most important country holding the biggest peatland area. Indonesian peatlands were distributed in three large islands, i.e. Sumatra, Kalimantan and Papua [2]. However, peatlands in Southeast Asia have become international debates over the past decades due to large-scale conversion of peat swamp forest to agricultural plantations [3, 4]. Due to this alteration, peatland as an immense C storage is vulnerable and swiftly thought as C source [5].

One of large peatland degradations in Indonesia was during the conversion of peat swamp forest to agricultural uses, known as the Mega Rice Project (MRP) in Central Kalimantan [6]. About a million hectare of peatlands were deforested in late 1990s for agricultural rice fields. Unfortunately, the project was failed, and large site of peatlands was abandoned to become shrublands. Conversion of peat swamp forest to plantations is usually accompanied by drainage canal construction. This drainage usually lowers ground water level (GWL) and potentially increases CO2 emission from peat soil [7, 8]. Moreover, due to existing drainage, peat subsidence rates potentially increase due to peat shrinkage and/or peat oxidation.

Measuring peat subsidence is widely known as an alternative approach to determine net C loss from peatlands. Usually, C is determined by measuring irreversible lowering peat soil surface, combined with peat characteristics [9]. This measurement has an advantage in providing a direct approach to C loss measurement that is easy to assess and to interpret directly in the field. Therefore, the result is expectedly accurate.
Alongside oil palm, rubber plantations have been expanding at a yearly basis. Different to oil palm plantations, development of rubber plantations in Indonesia was governed by smallholders, rather than industrial plantations [10]. The impact of peatland conversion on smallholder plantations is, however, understudied [11].

Indonesia’s tropical peatland experienced an extreme drought due to El Niño event in 2015 [12]. Because of the event, GWL further lowered because precipitation was dropped and dry season was prolonged [13]. Receding GWL potentially accelerates peat subsidence, thus, a study of peat subsidence associated with El Niño event is needed. The objective of this study was to assess the impact of different climatic conditions to peat subsidence by measuring the subsidence in dry season of a strong El Niño year compared to the one in a normal year. We hypothesized that peat subsidence in dry season with El Niño event was higher than the same condition in a normal year.

2. Methodology

2.1. Site location
The research study was conducted in a smallholder rubber plantation over peat soil in Pulang Pisau, Central Kalimantan, Indonesia. The age of rubber plantations was about 8 years, planted at interval of 3 x 6.5 m. Further details of the study site were provided in Wakhid et al. [14].

2.2. Peat subsidence measurement
Peat subsidence was measured in monthly-basis from June through November both in 2014 and 2015. The subsidence (in cm) during six months was determined by observing the difference of surface elevations between June and November, in 2014 and 2015. Temporal change was monitored from three measurement points between rubber trees. Metal rods were installed and inserted vertically into the peat, and were fixed in the underlying mineral soil. The height of metal rods was initially measured after installation, indicating the first mark of serial measurements.

![Figure 1](image.png)

Figure 1. Experimental design of metal rods for subsidence measurement and GWL pipe

2.3. Groundwater level measurement
Groundwater level (GWL) was defined as a relative depth of soil water surface to the soil surface. To measure this property, a PVC pipe with regularly-spaced holes was installed vertically submerged into peat soil. GWL was then recorded hourly using an automatic water pressure sensor (Hobo U20, Onset, Massachusetts, United States) deployed inside the pipe.
3. Results and discussion

3.1. Seasonal variations in environmental factors
Precipitation in dry season (with amount of less than 100 mm) was measured on monthly basis from July and August, both in 2014 and 2015 (Figure 2). Accumulating precipitation in 2015 was lower than in 2014. The lowest precipitation, only 0.9 mm, was recorded in September 2015, much lower than 32.6 mm seen in September 2014. The lowest precipitation in 2015 was shifted from 2014 observation, which was recorded in July (16 mm). The research found that averaged 2015 GWL was 47.5 cm lower, compared to 2014 case. Pattern observed from GWL resembled the one of precipitation. In strong El Niño event, precipitation was reduced; as a result, 2015 GWL was below normal. Despite varying lowest precipitation between 2014 and 2015, lowest GWL remained similar, i.e. in October. In 2015, the lowest GWL was one month later than the lowest precipitation.

![Graph A](image_a.png)
![Graph B](image_b.png)

**Figure 2.** Variations in daily (a) precipitation, (b) groundwater level (GWL) from 12 June to 30 November, in 2014 (grey line) and 2015 (black line). Precipitation was measured using a sensor in Edy covariance tower in Palangkaraya [15]

3.2. Peat subsidence
Peat subsidence in November 2015 was 8.28 cm lower than in November of 2014. The six month subsidence was measured to be -10.9 and -2.60 cm, respectively for 2015 and 2014 dry season. Peat subsidence in 2015 was significantly lower than in 2014. Peat subsidence during 6 month observation in 2015 was three times lower than the normal year. Surface elevation varied from -3.49 to -11.4 cm in 2015, and from -0.45 to -5.73 cm in 2014. Despite of short surface measurements, peat surface elevation showed a large variation (Figure 3).
Figure 3. Peat soil surface elevation relative to the initial value in June 2014 and 2015, respectively, from July to November of 2014 (grey line) and 2015 (black line).

Variation of peat soil surface was similar between 2014 and 2015. The lowest surface elevation was consistently found in October and was appeared to be consistent to the variation of GWL (Figure 4). The lowest peat soil surfaces in 2014 and 2015 coincided with the lowest GWL recorded in October for 2014 and 2015 observations. Therefore, peat subsidence during six month measurement in 2014 and 2015 was most likely to be overestimated, because surface elevation of peat soil is sensitive to GWL fluctuation. With that sense, GWL should carefully be considered to determine peat subsidence. The subsidence consists of peat oxidation, compaction, shrinkage, and consolidation [10]. Fluctuating peat soil surface following GWL was likely because of peat decomposition that significantly affected by GWL variation [15].

Figure 4. Variations of surface elevation and groundwater level (GWL) from July through November of 2014 (left), and 2015 (right), relative to that in June 2014 and 2015. Data were averaged from 3 metal rods ($n = 3$).

4. Conclusion
Peat subsidence on 2015 dry season, which coincided with a strong El Niño event, was three times lower than the one on its corresponding normal year. Variations of peat soil surface elevation varied in parallel with groundwater level (GWL). The lowest surface elevation was recorded in November, concurring with lowest GWL. This research suggests that GWL should be carefully considered to determine peat subsidence.
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ORCID IDs
Nur Wakhid https://orcid.org/0000-0002-5065-8770

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