Gmail novitasari ST.,MT. <novitasari.st.mt@gmail.com>

# Fwd: [JDR] Before accepting your submission RE: Manuscript for Journal of Disaster Research

**Joko Sujono** <jsujono@ugm.ac.id> 2 Agustus 2018 pukul 17.37
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>

---------- Forwarded message ---------
From: **JDR** <disaster@fujipress.jp>
Date: Thu, 2 Aug 2018, 16:28
Subject: [JDR] Before accepting your submission RE: Manuscript for Journal of Disaster Research
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Thank you for submitting your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

to the Journal of Disaster Research.

Before accepting your submission, we would like to ask
you the following:

1) Please fill out and submit a submission form (the template file attached).
Please let us know whether you intend to submit as Regular paper or for Special issue.

2) If you submit this paper as Regular paper, would you agree to pay the page charges
(12,000JPY per page) and the reprint (if necessary) costs if the above manuscript is
accepted for publication in JDR?
Detailed information can be found at
https://www.fujipress.jp/jdr/dr-authors/#page_charge

3) To clarify research positioning and purpose, authors should survey international literatures, including JDR publications.
It is strongly recommended that authors include JDR publications in references. All JDR papers can be freely searched and downloaded (OPEN ACCESS) at
https://www.fujipress.jp/jdr/dr/
Create your account for download for free at
https://www.fujipress.jp/usces-member/?page=newmember

We are looking forward to hearing from you soon.

Sincerely yours,

Aya Kamata (Ms.)
JDR Editorial Office
Fuji Technology Press Ltd.

******We have moved to the address below******
Address: Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
*Our e-mail address remains unchanged.

From: Joko Sujono [mailto:jsujono@ugm.ac.id]
Sent: Wednesday, August 01, 2018 5:23 PM
To: disaster@fujipress.jp
Subject: Manuscript for Journal of Disaster Research

Dear Shinya Wakai (Mr.).
JDR Editorial

We send you a manuscript of our research about wildfire in tropical peatland with the tittle "DROUGHT INDEX FOR PEATLAND WILDFIRE MANAGEMENT IN CENTRAL KALIMANTAN, INDONESIA DURING EL NIÑO PHENOMENON". We hope this paper could be published at JDR journal.

Thanks for your time.

Best regards,
Joko Sujono

**jdr_submissionform.doc**
40K

# Journal of Disaster Research

# Submission Form

| | |
|---|---|
| Title | Drought Index on Peatland Wildfires Management in Central Kalimantan, Indonesia, during El Niño Phenomenon |
| Language | ☐Japanese ☑English |
| Type | ☐Review ☑Paper ☐Development Report ☐Letter ☐Note ☐News ☐Discussion |
| Issue No. | Vol. No. |



| Name | Affiliation | Address | E-mail |
|---|---|---|---|
| Novitasari Novitasari | Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada | Jl. Grafika No 2, Yogyakarta, 55281, Indonesia | novitasari.st.mt@mail.ugm.ac.id |
| Joko Sujono | Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada | Jl. Grafika No 2, Yogyakarta, 55281, Indonesia | jsujono@ugm.ac.id |
| Sri Harto | Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada | Jl. Grafika No 2, Yogyakarta, 55281, Indonesia | sri.harto.b@ugm.ac.id |
| Azwar Maas | Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada | Jl. Flora, Bulak Sumur, Yogyakarta, 55281, Indonesia | azwarmaas@ugm.ac.id |
| Rachmad Jayadi | Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada | Jl. Grafika No 2, Yogyakarta, 55281, Indonesia | rjayadi@ugm.ac.id |

| | | | |
|---|---|---|---|
| Zip code | 55281 | | |
| Address | Jl. Grafika No 2, Yogyakarta, 55281, Indonesia | | |
| | | | |
| Affiliation | Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada | TEL: | +62 274 545675 |
| | | FAX: | +62 274 545676 |
| Liaison person | Prof. Ir. Joko Sujono, M.Eng., Ph.D. | E-mail: | jsujono@ugm.ac.id |

- E-mail communication: ☑possible ☐not possible
- galley proof copy in Acrobat PDF format: ☑acceptable ☐impossible

**Please use following checklist for preparation of a paper.**

☑ title ☑ abstract(about 300words) ☑keyword(within 5words) ☑text ☑references
☐ figures

Gmail **novitasari ST.,MT. <novitasari.st.mt@gmail.com>**

# Fwd: Notification of receipt: Dr9565

**Joko Sujono** <jsujono@ugm.ac.id> 10 Oktober 2018 pukul 17.39
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>

---------- Forwarded message ---------
From: **JDR** <disaster@fujipress.jp>
Date: Wed, 8 Aug 2018 at 08:19
Subject: Notification of receipt: Dr9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono

Thank you for your reply.
Now we accept your submission

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

to the Journal of Disaster Research.
Your manuscript ID is Dr9565.

Your paper is going to be reviewed.
You will be notified as soon as we receive the review results.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts
published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
--------------------------------------------------------------------------------

From: Joko Sujono [mailto:jsujono@ugm.ac.id]
Sent: Tuesday, August 07, 2018 10:20 AM
To: JDR <disaster@fujipress.jp>

Subject: Re: [JDR] Before accepting your submission RE: Manuscript for Journal of Disaster Research

Dear Ms. Aya Kamata,

Thank you very much for the quick response of my email.
Enclosed the file needed for submission:
1. A copy of a submission form.
2. We like to submit as regular paper and agree to pay the page charges.
3. We have revised our manuscript, and include 3 paper in JDR publications in references, with the similar research area in tropical peatland.

I thank you for your kindness.

Best regards,
Joko Sujono

On 2 August 2018 at 16:28, JDR <disaster@fujipress.jp> wrote:
Dear Dr. Joko Sujono,

Thank you for submitting your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

to the Journal of Disaster Research.

Before accepting your submission, we would like to ask
you the following:

1) Please fill out and submit a submission form (the template file attached).
Please let us know whether you intend to submit as Regular paper or for Special issue.

2) If you submit this paper as Regular paper, would you agree to pay the page charges
(12,000JPY per page) and the reprint (if necessary) costs if the above manuscript is
accepted for publication in JDR?
Detailed information can be found at
https://www.fujipress.jp/jdr/dr-authors/#page_charge

3) To clarify research positioning and purpose, authors should survey international literatures, including JDR publications.
It is strongly recommended that authors include JDR publications in references. All JDR papers can be freely searched and downloaded (OPEN ACCESS) at
https://www.fujipress.jp/jdr/dr/
Create your account for download for free at
https://www.fujipress.jp/usces-member/?page=newmember

We are looking forward to hearing from you soon.

Sincerely yours,

Aya Kamata (Ms.)
JDR Editorial Office
Fuji Technology Press Ltd.

******We have moved to the address below******
Address: Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
*Our e-mail address remains unchanged.

From: Joko Sujono [mailto:jsujono@ugm.ac.id]
Sent: Wednesday, August 01, 2018 5:23 PM

To: disaster@fujipress.jp
Subject: Manuscript for Journal of Disaster Research

Dear Shinya Wakai (Mr.).
JDR Editorial

We send you a manuscript of our research about wildfire in tropical peatland with the tittle "DROUGHT INDEX FOR PEATLAND WILDFIRE MANAGEMENT IN CENTRAL KALIMANTAN, INDONESIA DURING EL NIÑO PHENOMENON". We hope this paper could be published at JDR journal.

Thanks for your time.

Best regards,
Joko Sujono

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari*1, Joko Sujono*1,†, Sri Harto*1, Azwar Maas*2, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

__X__ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Major comments:

Comment #1:

The repetitive text in Introduction, KBDI Index and some modifications, and Data sections in Lines 66-98, 154-196, 297-315, and 363-391 have similar information. The essential information should be greatly condensed to 1-2 sentences or moved to the discussion section. However, the introduction of various drought types is rather limited, see Line 114-127, and should be expanded especially in relation to groundwater levels. The authors should describe their drought using commonly drought terminology in peer-reviewed literature when referring to investigated drought types: meteorological (lack of precipitation), agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows) and socio-economic (lack of water supply to meet water demand) (Gusyev et al., 2015, 2016), which should be included. In addition, the authors could include WMO (2012; 2016) about various existing and new drought indices in Lines 128-153.

Comment #2:

The current structure of the manuscript has repetitive equations and text. Equation (1) is repeated by Equations (4)-(7), which have different coefficients of wc, a and b and should be removed. Instead, these coefficients should be given in new Table including computed evaporation time, t26.7, with annual rainfall values. Instead, the authors should add the formula of computing evaporation time. Therefore, I suggest to remove equations (4)-(7) by introducing values of coefficients in a new Table.

References:

Gusyev M.A., Hasegawa A., Magome J., Sanchez P., Sugiura A., Umino, H., Sawano H. and Y. Tokunaga (2016). Evaluation of water cycle components with standardized indices under climate change in the Pampanga, Solo and Chao Phraya basins. Journal of Disaster Research 11(6): 1091-1102, doi: 10.20965/jdr.2016.p1091

Gusyev M.A., Hasegawa A., Magome J., Kuribayashi D. and H. Sawano (2015). Drought assessment in the Pampanga River basin, the Philippines - Part 1: Characterizing a role of dams in historical droughts with standardized indices. In Weber, T., McPhee, M.J. and Anderssen, R.S. (eds) MODSIM2015, 21st International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2015: 1586-1592 pp. ISBN: 978-0-9872143-5-5.

World Meteorological Organization (WMO) (2012). Standardized Precipitation Index User Guide (M. Svoboda, M. Hayes, and D. Wood). WMO-No. 1090, Geneva.

World Meteorological Organization (WMO) (2016). Handbook of Drought Indicators and Indices. WMO-No. 1173, Geneva, 52 p.

Minor comments:

Line 40: Please clarify “other water table reference”?

Line 106: delete “Singapore”, which is not a country.

Lines 87-88: Do you fire? Smoke does not cause the loss of lifes and property.

Lines 114-127: see my major comment #1 to include all drought definitions.

Line 131: change “its impact” to “its impacts”

Line 134: Did you mean aridity index by Thornthwaite (1948)? Please include WMO (2012; 2017) references, see my comment #1.

Line 189: since it is now use, please remove the “WTF” acronym.

Ling 212 Equation 1: “ KBDIt = KBDIt +“ should be “KBDIt = KBDIt-1 + “

Line 238: Incorrect replace style and change to “[38]”

Line 255: Add reference [38].

Line 260: Remove “n” in “coefficient an”

Line 262: Incorrect style and change to “[38]”

Line 270: Incorrect style and change to “[43]”

Line 276: Incorrect style and change to “[38]”

Line 287: Incorrect style and change to “[43]”

Line 361: Re-name “Data” to “Study area and Data” Section

Line 362: Remove sub-section title.

Lines 392-411, Figure 1. Could you enlarge insets? It is very difficult to see details of canals.

Line 431: Remove sub-section title.

Line 448: Move “Methods” sub-section to “Methods” section.

Figure 2 & 3: This figures should be merged giving the same time-scale. Legends should be placed within figure

Line 673: References formatting is shifted and needs to be fixed to [].

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

_________ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

___○___ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Thank you for the paper discussing on KBDI and NFA relationships for mainly 2015.

My comment is as follows.

It is better to re-structure your paper. For example, you use 3. Data, 3.2 Data, 4.1 Rainfall Data, 4.2 Number of fire alerts data even the chapter 4 is Results and discussion.

Figure 2 and 3 ; Because we can know these figures for 2015, write horizontal axis simply.

Figure 3 and 4 ; Show vertical gridlines indicating months.

L207, 338 and 463 $\mathrm{R}_0$ -> $R_0$

L212 check equation (1).

L225 write as "5.1 mm/day"

L240 replace *x* with space, *a*. -> *a* and -0.001736.-> -0.001736

L260 coefficient *an* -> coefficient *a*

L265,285,293 and 345 $KBDI^{t-1}$ -> $KBDI_{t-1}$ replace *x* with space

L338 and 463 You wrote "$R_0$ =65" inches while you defined $R_0$ in mm/year in line 249.
L392-406 These pictures are very small and readers don't find what you want to show.
L421-426 "This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke indicates the landfill condition [53]" looks to show the explanation of Figure 1.b. But I cannot find "red line" in Figure 1.b.
L461-463 You showed "annual rainfall of 1600 mm". You discussed on the drought from September to November using 1600mm which include rainfall occurred after drought. Is it better take annual rainfall before dry season such as Oct to Sep?
L488 Show legend more clearly. Readers cannot distinguish them.
L587-588 You wrote "the extreme index level at the value of 375 and continues to rise to the maximum value of 400 starting on September 12, 2015 ", but I cannot find 375 and 400 in Figure 3 and 4. Could you explain more about it.
L563 R0 -> $R_0$
L564-566 "high to extreme drought level was obtained starting from September to November 2015 as much as 51 indices" -> "extreme drought level was obtained starting from September to November 2015 as much as 51 indices"
L632-634 Could you explain from which you derived this knowledge.

Result and discussion ; Your analysis based on number of monthly events while you have daily base data. If you analyze in daily or weekly base, you may get more detail result.

UGM Mail **Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>**

# Fwd: Notification of review result: Dr9565

**Joko Sujono** <jsujono@ugm.ac.id> Wed, Mar 13, 2019 at 7:44 AM
To: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>, Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Tue, 12 Mar 2019 at 15:57
Subject: Notification of review result: Dr9565
To: <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

We have just received the reports on your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

In view of the reviewers' comments,
some changes are necessary for acceptance.
Please revise your manuscript based on the attached
reviewers' comments and send it to us by April 2.

Please note that revised sentences should be indicated by color characters or color highlights in the revised manuscript.

We look forward to receiving your answer to reviewers
and revised manuscript (electronic file).

*Referring to publications of the Journal of Disaster Research in your paper is strongly recommended.
All papers of the Journal of Disaster Research can be freely searched and download at
https://www.fujipress.jp/jdr/dr
Creat your account (free) on:
https://www.fujipress.jp/usces-member/?page=newmember

Thank you

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)

*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts
published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
----------------------------------------------------------------------------------

**3 attachments**

**jdr_reviewform_b1.pdf**
157K

**jdr_reviewform_a1.pdf**
47K

**Cover_responsepage.doc**
35K

**Paper :**

# Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

**Novitasari Novitasari*1, Joko Sujono*1,†, Sri Harto*1, Azwar Maas*2, and Rachmad Jayadi*1**

*1 Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Jl. Grafika No 2, Yogyakarta, 55281, Indonesia
† *Corresponding author. Tel.: +62 274 545675; Fax: +62 274 545676, E-mail address: jsujono@ugm.ac.id*
*2 Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Jl. Flora, Bulak Sumur, Yogyakarta, 55281, Indonesia

**Peatland wildfires, especially in tropical ecosystems are due to drought and have caused smoke and other related problems in all aspects of community life in Indonesia, especially in Central Kalimantan. Drought is worsened by the number of drying days in the dry season, El Niño phenomenon, and drainage system in a peatland. Drought decreases the water table and triggers wildfire in a peatland. This research aims to modify numerical formula of drought factor (DFt) in the Keetch–Byram Drought Index (KBDI) of tropical peatland wildfire condition in Central Kalimantan during El Niño phenomenon in 2015 and to apply peatland water table reference are about 400 mm below the ground surface based on previous research and the Government regulation on peatland ecosystem protection and management in Indonesia. This El Niño conditions caused about 30% rain decline in Block A, Ex-Mega Rice Project (EMRP), Mantangai sub-District, Kapuas District, Central Kalimantan Province. The modified KBDI is compared with the Number of Fire Alerts (NFA) by using NASA's active Fire Data in 2015. The analysis results show that modified DFt under tropical peatland conditions leads to an increase in the drought index value, which begins on the predominant drying day in July to October 2015. The extreme KBDI drought index increased from 375 to 400 from September to November 2015 as much as 51 extreme drought indices became an indicator for peatland wildfire risk assessment. The extreme KBDI is directly proportional to the number of NFA recorded during 2015, and the highest number of fire occurred in October 2015, with as much as 1746 hot spots with 25 days extreme drought indices from 27 drying days. Hence, the modified formula is suitable for this peatland wildfire condition in Central Kalimantan. Overall, the modified DFt could be applied to El Niño phenomenon and other water table reference under different land conditions.**

**Keywords:** Keetch–Byram drought index, Drought factor, Number of Fire Alerts, El Niño, peatland wildfire

## 1. Introduction

The forest wildfire in Indonesia in 2015 is the largest wildfire in the last ten years in terms of the amounts of trace gases, and aerosols released [1]. The severity of this wildfire is similar to the disaster that occurred in 1997 [2]. Forest wildfires in Indonesia not only occur in upland but also in wetlands [3]. These forest wildfires mainly occur in tropical peatlands [4]. Wildfires in tropical peatland occupy an area equivalent to 10.8% of the Indonesia's land area [5]. Among tropical countries, Indonesia has the largest tropical peatland, which is about 14 million ha and mainly spreads in Sumatra, Kalimantan, and Papua [6]. Indonesia's peatland is a part of the tropical peatland in Southeast Asia [7]. Tropical peat comprises accumulated organic materials in a wetland ecosystem [8]. A tropical peat is formed in forests under wetland conditions with the production of large quantities of organic materials [9, 10]. Organic materials include trees in tropical forests [7].

Indonesia's peatland is developed by building a drainage system. Canals are intended to decrease the water table in the peatland. These canals are utilized to support the cultivation of crops, such as oil palm and acacia. The decrease in the water table can cause the peat to become over drained and more flammable, thereby damaging the ecological balance and eliminating forest and peatland biodiversity [10]. Peatland is commonly burned by people to minimize production cost, but this practice may cause uncontrolled peatland wildfires [11]. In addition to human-caused fires, peatland wildfires are caused by meteorological drought factors, such as lack of rainfall and high evaporation rate [12]. The water table also decreases due to drain and causes wildfire risk. Dry peatland, which is fundamentally unstable, will lose water from the pores of the soil, allowing oxygen to penetrate into the pores and oxidize the peat through biological and chemical processes [13]. Peatland wildfires not only cause rainforest degradation [14] and affect biodiversity [15] but also release smoke from carbon emissions to the atmosphere; smoke harms the human body and leads to loss of lives and property [16]. Peatland wildfires spread slowly through the surface, and those classified as smoldering type are absorbed by subsurface and organic layers

[17]. This type of fire is difficult to be detected [18]. Smoldering wildfire causes the lateral spread of flames under different moisture and wind conditions [19] and creates strong smoke that spreads over extensive areas [20]. Drought and fires are important components for the dynamics assessment of tropical peat forests [21].

The risk of wildfires increases due to frequency and duration of drought [22]. Drought is a condition that cannot be managed [23] and has affected millions of square kilometers of land in many areas, such as North America, West Africa, and East Asia [24]. In Indonesia, drought in peatlands causes wildfires as sub-surface fires all around the ecosystem. These wildfires cause smoke to spread to other countries, such as Malaysia [25] and Singapore. Fires occur almost every year in Indonesia during the dry season. Wildfires usually occur between June and September and will intensify during El Niño [26]. El Niño is a natural phenomenon characterized by the warming of temperatures in the Pacific Ocean and causes drought in the Asian region [27]. El Niño decreases the amount of rainfall in Indonesia [16].

A situation with less than normal water availability due to climate variability may cause drought [28]. Decreased amount of rainfall is also one of the causes of drought, namely, meteorological drought [29]. This type of drought appears in various components of the hydrological cycle [30]. In Indonesia, meteorological drought is accompanied by dry peatland caused by the decline in the water table and changes in the physical properties of peat due to the drainage system. Drainage system forces water to fall from the land to the drains and continue to the water body. Internal factors cause the land to become drought and flammable. Some fires are also caused by human activities, such as land clearing.

Drought causes wildfires in a complex process, and drought index cannot be easily specified. No index can explain the complexity of drought and its impact [31]. In a previous meteorological drought analysis, the ratio between the amount of available water, especially rain, and the amount of water loss due to evaporation process is called drought index. Furthermore, the drought index can be used as indicator to determine the classification of the drought level of a particular region or area [28]. Many drought indices have been expanded to appraise the scale, type, and impact of drought [32]. In forestry, many drought indices are designed for fire risk assessment [33]. The most widely used drought indices are the Nesterov index, the Zhdanko index [34], the Angstrom Index [35], the Baumgartner index [36], the McArthur forest fire danger index [37], and the Keetch–Byram Drought Index (KBDI) [38]. KBDI is one of the most widely used indices for forest fire control management under various climatic conditions [31]. KBDI was first developed for forest fire control management in the sub-tropical Florida region in USA [38]. KBDI was also developed to be suitable under Mediterranean conditions. This study provides accurate results in forestry and fire risk management in Thessaloniki, Northern Greece [39].

A previous study of Petros, et al (2011) obtained a high response between the modified KBDI in a Mediterranean climate to the data of real moisture in the region. The modified KBDI used under rainfall conditions in Mediterranean takes on higher values during summer months to estimated fire risk in that study area [39]. The modified index in Mediterranean climate was verified by testing the KBDI of pine forests in the southwestern province of Valencia, Spain under sub-tropical and Mediterranean climate conditions in terms of tree growth density and water balance for forest fire control [40]. The application of KBDI in the Hawaiian Islands under sub-tropical and Mediterranean climate conditions shows that it can represent fire activity in the region. This research concludes the strong relationship between KBDI and total burned area in Oahu, Maui and Hawaii islands [41]. KBDI was also tested on four rain stations in Malaysia, namely, Kota Bharu Station (Kelantan), Kuching (Sarawak), Sandakan (Sabah), and Subang (Selangor). The KBDI scores obtained in these stations were used to present trends that can be used in forest fire management in Malaysia that has tropical climate [42]. The KBDI in Indonesia was also applied to wetlands in Ogan Komering Ilir, South Sumatra and lead to more accurate results in predicting fire hazards in wetland areas by adding water table factor (WTF). The critical water table to achieve the maximum fire hazard is 0.85 m for the wetland forest area in the area [43]. KBDI was also used by the International Forest Fire Management Project for forest fire control in East Kalimantan and exhibited more accurate result than the Nesterov index [44]. Evaluation of the performance of KBDI under some climatic conditions, ranging from sub-tropical climate, Mediterranean climate, and tropical climate, reports that KBDI is a flexible drought index for almost all climatic conditions and may represent forest fire control. Therefore, this study aims to test the behavior of KBDI for peatland wildfires in Central Kalimantan under tropical climate conditions affected by the El Niño disaster in 2015. This El Niño conditions caused significant rainfall decline in most parts of Indonesia.

## 2. KBDI Index and some modification

### 2.1 KBDI and wildfire risk assessment

KBDI was first introduced to manage forest fire control under sub-tropical climate. This index represents the net effect of evapotranspiration and precipitation on cumulative moisture deficiency in deep duff or upper soil layers and is related to the flammability of organic materials in the ground [38]. KBDI is applied to human activity-caused fire and sub-surface fire. Under sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm/year, the maximum temperature ($T_m$) is 26.7 °C, and the corresponding field capacity of available water in the layer ($w_c$) is 203 mm. KBDI is determined using Equation (1).

$$KBDI_t = KBDI_t + DF_t - RF_t \quad (1)$$

where:
$DF_t$ = drought factor (mm)
$RF_t$ = rainfall factor (mm)
$t$ = time (day)

The value of rainfall factor ($RF_t$) is determined by meteorological data in the form of annual rainfall and daily rainfall. $RF_t$ more than 5.1 mm/day is considered a reduction in the drought index and determined with the following equation [38].

$$RF_t = \begin{cases} (R_t - 5.1), R_t \geq 5.1\frac{mm}{day}, 1st\ rainy\ day \\ R_t,\ R_{t-1} \geq \frac{5.1mm}{day}, 2nd\ and\ the\ next\ rainy\ day \\ 0,\ R_t < 5.1mm/day \end{cases} \quad (2)$$

Drought factor ($DF_t$) was determined based on the basic theory of soil moisture degradation in the forest area for fire control by assuming the following: (1) the field capacity of the organic layer is taken as 203 mm of water in excess of moisture hold by the layer at the wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall (Keetch & Byram, 1968) as follows:

$$DF_t = (w_c - KBDI_{t-1})x\frac{(a.e^{(bxTm+1.5552)} - c)x10^{-3}}{1+10.88.e^{(-0.001736.R_0)}} \quad (3)$$

where:
$DF_t$ = drought factor (mm)
$w_c$ = the corresponding field capacity of available water in the layer (mm)
$KBDI_{t-1}$ = moisture deficiency (KBDI at t-1)
$Tm$ = daily maximum air temperature (°C)
$t$ = time increment (day)
$R_0$ = average annual rainfall (mm/year)
$a$ and $c$ = coefficient influenced by the mean annual rainfall ($R_0$)
$b$ = coefficient influenced by evapotranspiration

Based on calculations in the Forest Service Research paper SE-38, the evaporation time for 26.7 °C and the annual rainfall of 1270 mm/year ($t_{26.7;1270}$) is 56.41 days; this value is only affected by temperature. The evaporation time for the temperature of 26.7 °C and the annual rainfall of ∞ mm/year ($t_{26.7;\infty}$) is 0.4545.$t_{26.7;1}$= 25.64 days. The coefficient *an* in Equation (3) become 0.968, and the coefficient *c* become 8.3 (Keetch & Byram, 1968); thus, Equation (3) becomes Equation (4).

$$DF_t = \frac{(203 - KBDI^{t-1})\,(0.968e^{(0.0875xTm+1.5552)} - 8.3)x10^{-3}}{1+10.88e^{(-0.001736xRo)}} \quad (4)$$

## 2.2 KBDI index modification in tropical climate

### 2.2.1 KBDI index modification in tropical wetland conditions

Taufik et al. (2015) modified $DF_t$ affected by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients *a* and *c* in Equation (3) adjusted to the annual rainfall ($R_0$) in tropical climate. The mean annual rainfall in tropical climate is 2500 mm [43]. The evaporation time for the same temperature used by Keetch & Byram (1968) is 26.7 °C, and the annual rainfall for the tropical climate of 2500 mm/year ($t_{26.7;2500}$) is 56.41 days. The evaporation time for 26.7 °C with an annual rainfall of ∞ mm/year ($t_{26.7,\infty}$) is equal to 0.8831.$t_{26.7;2500}$= 49.8 days. The coefficient *a* becomes 0.4982, and the coefficient *c* becomes 4.268. Equation (4) becomes Equation (5).

$$DF_t = \frac{(203 - KBDI^{t-1})\,(0.4982e^{(bxTm+1.5552)} - 4.268)x10^{-3}}{1+10.88e^{(-0.001736xRo)}} \quad (5)$$

Taufik et al. (2015) concluded that the loss of evapotranspiration in tropical climate is higher than 15% relative to that in sub-tropical climate; thus, the coefficient *b* in Equation (5) becomes 0.0905 as in Equation (6).

$$DF_t = \frac{(203 - KBDI^{t-1})\,(0.4982e^{(0,0905xTm+1.5552)} - 4.268)x10^{-3}}{1+10.88e^{(-0.001736xRo)}} \quad (6)$$

### 2.2.1 KBDI modified under tropical conditions followed by El Niño

The formula of $DF_t$ [Equation (6)] has been developed to represent the average rainfall conditions in wildfire risk control for tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, and the amount of rainfall is below the normal conditions [27]. In 2009, in the Southern part of Kalimantan shows low precipitation, which causes peatland drying and easy spread of fires [45]. Analysis of rainfall from three stations in the study area indicates that when El Niño happened in 2015, rainfall decreased by approximately 30% of the annual average rainfall in tropical climate. The annual rainfall at the study area was 1600 mm in 2015. The decrease in rainfall affects the values of the coefficients *a* and *c* on $DF_t$ in Equation (6).

In addition to the changes in the coefficients *a* and *c* on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 of soil water available for evapotranspiration and expressed in hundredths of a millimeter [38]. The $w_c$ value was on the scale from 0 to 203, where 0 shows no moisture depletion and 203 indicate the highest depletion [43]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on a peatland research in the Netherlands that 400 mm depth of reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire and reduction of groundwater level [46]. The Government Regulation of the Republic of Indonesia No. 71 of 2014 [47] on peat ecosystem protection and management of clause 23 point 3, that was revised into regulation No. 57 of 2016, stating that peat ecosystem with cultivation function could be damaging if water table depth is more than 400 mm below the peat surface [48].

Based on the average rainfall data of 2015 and water table data, the evaporation time at 26.7 °C and the annual rainfall of ∞ mm/year ($t_{26.7;\ \infty}$) is $0.6175.t_{26.7;1600}$ = 68.6 days for $R_0$ = 65 (1600 mm). Based on the values the coefficient $a$ become 0.3614 and the coefficient $c$ become 3.1027. The $w_c$ value used is 400 mm, which is according to the criterion of the water table reference for peat conditions. Equation (6) becomes Equation (7).

$$DF_t = \frac{(400-KBDI^{t-1})(0.3614e^{(0.0905xTm+1.6096)}-3.1027)x10^{-3}}{1+10.88e^{(-0.001736xRo)}} \quad (7)$$

The new value of $w_c$ causes a change in KBDI classes. The water table ranges from 0 to 400 mm. The water table at 400 mm below the surface is considered to cause the maximum drought index and cause a fire risk in peat ecosystem. A water table of 0 mm, where water is on the surface of the land, is expressed as an ideal peat condition that is always inundated. Based on the result of the correction of $DF_t$ as in Equation (7), the value of KBDI classes that adjusts to the change of $w_c$ value is corrected. Drought index classes are divided into four levels as in Table (1).

Table 1. Drought index classes of KBDI modified for tropical peatland conditions

| KBDI index in tropical peatland conditions | classes |
|---|---|
| 0 – 200 | low |
| 201-300 | moderate |
| 301-350 | high |
| >350 | extreme |

## 3. Data

### 3.1 Description of the study area

The Mega Rice Project of one million hectares of peatland in Central Kalimantan damaged the tropical peat forest [49]. The present study was conducted in Block A, the Ex-Mega Rice Project (EMRP) located in Mantangai sub-District, Kapuas District, Central Kalimantan Province (Figure 1). The area undergoes land clearing, which causes the peatland to become dry and flammable. Drought index for peat wildfire risk assessment was evaluated under peat wildfires conditions in 2015. The largest wildfires occur in tropical peatlands, one of which is in a tropical peatland in Indonesia. Peat wildfires also occur in the EMRP area in Central Kalimantan [50]. The Mega Rice Project was opened in 1996 until 2009 and caused 400 thousand ha of tropical rainforest to be opened. EMRP is a program that considerably fails to conserve peatland in Indonesia [49]. The exploitation of forest and peatland in EMRP land occurs with the construction of drainage networks systems [49]. The drainage network systems divide peat domes, causing massive damage to peat dome, resulting in its loss of function as field reservoirs, land subsidence, and decreased water table [51]. This phenomenon causes irreversible drying peat, which triggers forest and peatland wildfires [52]. In addition to decreased water table, peatland wildfires are due to rainfall reduction (the number of drying day) due to the El Niño phenomenon, which usually occurs from September to October.


Figure 1.a. Study area on Block A of Ex-Mega Rice Project, b. The conditions of peatland wildfires was found on October 19, 2015, c. post-wildfire conditions in peatlands around canal C, d. Canal D post-wildfire, and e. Canal E post-wildfire in November 2015

Figure (1.a) shows the location of present research on the Block A of the EMRP in Mantangai sub-District, Kapuas District, Central Kalimantan Province. The areas studied include C, D, and E canal. The highest number of fire alert (NFA) was found on October 19, 2015. The conditions of peatland wildfires in Kalimantan captured by the Moderate Resolution Imaging SpectroRadiometer (MODIS) from the NASA Aqua satellite are presented in Figure 1.b. This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke indicates the landfill condition [53]. Figure 1.c shows some post-wildfires conditions in the peatland around C canal. Figure 1.d shows post-wildfires around D canal and Figure 1.e shows around E canal in the Block A of EMRP in Mantangai sub-District on November 2015.

### 3.2 Data

Rainfall data were recorded near the study area, such as in Tjilik Riwut, Beringin, and Sanggu Rain Station (http://dataonline.bmkg.go.id). Rainfall data were analyzed from 01 January 2015 to 31 December 2015, and the total dry days were 263 days, which are more than 70% from the total in 2015. The NFA in the form of hotspots was obtained from http://fires.globalforestwatch.org by using NASA's Active Fire Data to determine the possible location of fires on earth. The system uses NASA MODIS satellites, which survey the entire earth every 1–2 days. The sensors on these satellites detect hot marks in infrared spectral waves. During processing of the satellite imagery, the algorithm looks for a heat sign and detects it as a fire sign. The system can indicate where a fire occurred and can give warning [54].

### 3.3 Methods

In this study, a modified KBDI was developed for wildfire risk assessment under tropical peatland conditions influenced by El Niño; modification to baseline groundwater conditions for peatland affects the $w_c$ value. The modified index was compared with KBDI under tropical wetland conditions [43]. The results of two index modifications were compared against NFA recorded in peat forest, Block A, Mantangai Sub-district, Central Kalimantan Province, on 2015.

## 4. Results and discussion

### 4.1 Rainfall Data

Based on observations, rainfall from the three rain stations is almost uniform, with an average annual rainfall of 1600 mm ($R_0$ = 65 in). This rainfall value is below the average annual rainfall of areas with tropical climate. The mean annual rainfall under tropical climate ranges from 2000 nm to 3000 mm [43]. The decrease in rainfall is caused by El Niño in Indonesia. The average monthly rainfall at the three stations in the study site is the highest (134 mm) on November 2015. The net rainfall or rainfall factor (*RF*) is calculated with Equation (2) to determine the number of drying days (Figure 2). Drying day conditions in July as much as 30 days, 28 days in August, 30 days in September and 27 days in October 2015.

### 4.2 Number of fire alerts data

NFA data during 2015 in Mantangai, Central Kalimantan is shown in Figure 2. On that year, the NFA reaches as many as 30,121 events in Central Kalimantan Province and 3,544 events in Mantangai sub District. The NFA event in Mantangai is 3525 events from July to November 2015, as much 12.1% from 29171 events in Central Kalimantan. NFA began to increase from July to November 2015, and the largest number of NFA on October 2015 is as many as 1741 events in Mantangai. These data show that the number of hotspots in October represents half of the NFA over the year 2015.

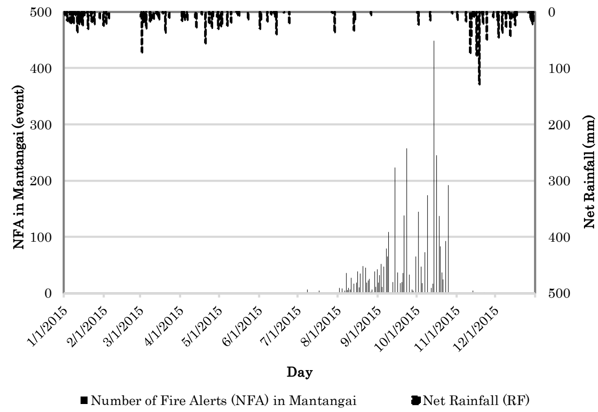



Figure 2. Net rainfall/rainfall factor ($RF_t$) and number of fire alerts (NFA) in 2015

### 4.3 Keetch-Byram Drought Index (KBDI) analysis

Based on the results of the analysis using $DF_t$ under tropical wetland conditions [43] and under tropical peatland conditions influenced by El Niño phenomenon, the change in the $w_c$ value is shown in Figure 3.

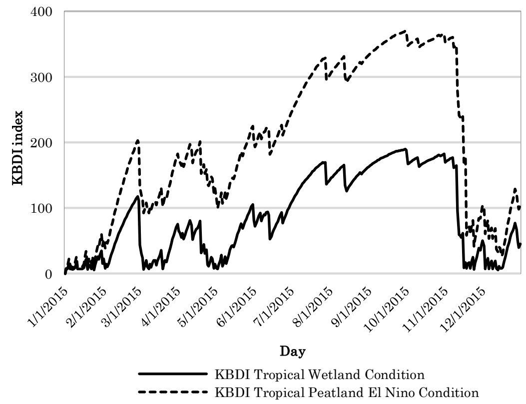



Figure 3. Comparison of KBDI tropical wetland conditions and modified KBDI of tropical peatland conditions influenced by El Niño phenomenon

The KBDI level with $DF_t$ formula under tropical wetland conditions of low-drought index level was 222 data, the medium drought index was 43 data, the high drought index as much as 65 data, and the extreme drought index was 35 data. In the calculation of KBDI with modified $DF_t$ formula under tropical peatland conditions, which was influenced by El Niño phenomenon, the extreme drought conditions increase to 51 occurrences, which started in September until November 2015. The extreme conditions are presented in Table 2.

Table 2. Extreme drought level conditions

| | July | August | Sept | Oct | Nov |
|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| KBDI tropical wetland conditions | High | 13 | 16 | 10 | 18 | 8 |
| | Extreme | 0 | 0 | 20 | 13 | 2 |
| KBDI modified in tropical peatland conditions due to El Niño | High | 13 | 27 | 11 | 6 | 3 |
| | Extreme | 0 | 0 | 19 | 25 | 7 |
| Number of Fire Alerts (NFA) | event | 19 | 488 | 1272 | 1746 | 10 |

Based on the 30% reduction in rainfall occurring at the study area in 2015 due to El Niño and the change in $w_c$ caused by groundwater table change, the extreme drought index increased. In calculating KBDI with $DF_t$ formula under tropical wetland conditions and tropical peatland conditions, extreme drought levels began to occur in early September 2015. KBDI response with a formula under tropical wetland conditions with KBDI with $DF_t$ under tropical peatland conditions was affected by El Niño against fire risk assessment represented by some fire points (NFA). The association of KBDI with $DF_t$ formula under tropical wetland conditions and the $DF_t$ formula correction of tropical climate affected by El Niño compared with NFA in the study area is shown in Figure 4.

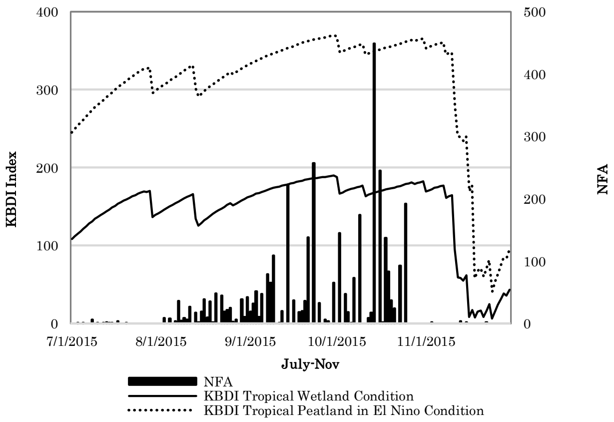



Figure 4. KBDI modification in tropical climate with NFA events in dry months (July to November 2015)

Figure 4 shows the high to the extreme drought index from the beginning of July to November 2015, representing the occurrence of a starting point of fire beginning in July 2015 from KBDI modification under tropical wetland conditions and tropical peatland conditions.

1. Index response with $DF_t$ formula under tropical wetland conditions
   Based on the analysis of KBDI with $DF_t$ formula on tropical wetland conditions, no extreme drought occurred at the beginning of July and August. Extreme drought indices occurred in September 2015 as many as 20 events, October 2015 as many as 13 events, and November 2015 as much as two events. Based on NFA data recorded in July, the study site has 19 hotspots, followed in August 2015 (488 hotspots) and September 2015 (1272 hotspots); most events as many as 1746 hotspots occurred in October. The highest level of extreme index occurred in September 2015 is not equal to the highest NFA on October 2015.
2. KBDI responds with corrected $DF_t$ under tropical peatland conditions
   In the corrected $DF_t$ formula for tropical peatland conditions affected by El Niño with rainfall reduction of 30% with R0 = 1600 mm and groundwater level 400 mm, high to extreme drought level was obtained starting from September to November 2015 as much as 51 indices. The results are extreme drought index of 19 events in September, 25 events in October, and seven events in November 2015. This finding is consistent with the presence of NFA data, where the starting point of fire in July to the highest fire spots in October 2015 as many as 1746 hot spots. Those hot spot conditions in October 2015 are represented by extreme drought conditions that covers 25 days of the month.

## 4.4 Discussion

Based on KBDI analysis in 2015 between corrected $DF_t$ modification under tropical wetland conditions and tropical peatland conditions compared with the number of fire alerts in Mantangai sub-District, the results show that:

1. The faster response of KBDI modification index under tropical peatland conditions adequately represents real fire risk assessment recorded in 2015. KBDI modification under tropical peatland conditions increases from the high index level to the extreme index level at the value of 375 and continues to rise to the maximum value of 400 starting on September 12, 2015, representing NFAs of as much as 20 events that day. KBDI modification under tropical wetland conditions increases from high index level to extreme index level on September 11, 2015, with only represented by 1 NFA data. That extreme level of KBDI modification under tropical peatland conditions could potentially trigger wildfires in peatland.
2. In October 2015, the NFA events in Mantangai are as many as 1746 events with the KBDI modification under tropical peatland conditions shown by 25 extreme indices while in KBDI wetland modification only indicated by 13 extreme indices.
3. According to the modified $DF_t$ under tropical peatland conditions, the estimated fire danger is higher than 16 indices in September to November 2015 in the study area with the corrected water table into 400 mm.

Modified KBDI under tropical peatland conditions seems to perform better in wildfire risk assessment of the peatland during El Niño in 2015 compared with other empirical KBDI parameters. The results are accordance with those of previous Kalimantan Forests and Climate Partnership (KFCP) observations. Based on a study of KFCP from 2004 to 2013 in the study area, daily wildfires indicated fire at the same location and month. Fires occur in late July to early November. The peak of the fire occurred in September [55]. Previous research on the smoke hazard posed by forest wildfires from 2001 to 2010 showed a large landfill trend occurring from mid-August to end of October [56]. Thus, by consideration the drought index formula under tropical peatland conditions have several general principles about the use of any empirical drought indices are:

1. The KBDI formula should be based on the net rainfall factor set by the R threshold. This threshold for tropical conditions still uses the same threshold in the previous KBDI formula defined under sub-tropical conditions.
2. Peatland wildfires are not just caused by meteorological conditions but also by many internal factors in the soil, such as peat decomposition, physical properties, water holding capacity, and capillarity rise.
3. Peatland wildfires are also affected by peatland unwise management, similar to building drain canal in the peat dome that changes water table.

## 5. Conclusion

KBDI modification by correcting $DF_t$ formula against the referenced water table level for peatland and influenced by rainfall reduction due to the El Niño phenomenon can represent NFA in peatland. The analysis results show the behavior of the KBDI of drought correction ($DF_t$) under tropical peatland conditions already represented by some drying days dominant occurring from July to October 2015. The extreme index increasing from 375 to reach a maximum value of drought index of 400 occurred from September to October 2015 become the indication of peatland wildfires risk assessment. 25 days extreme index from 27 drying days in October 2015 that represented as many as 1746 hotspots of peatland wildfires occurred in the research area. It indicates that formula modification is suitable for this condition. Finally, based on this research, the modified $DF_t$ can be applied to El Niño phenomenon and other water table reference under different land conditions. In addition to meteorological and water table factors that affect drought management in peatland, several supporting factors must be considered, such as peat decomposition, physical characteristics, water holding capacity, and capillarity rise. The lower physical properties of peatland lead to larger wildfires with the same number of drying days.

**Acknowledgments**

This study was completed with partial funding Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) from the DRPM Ditjen Penguatan Riset dan Pengembangan, Ministry of Research, Technology, and High Education – the Republic of Indonesia through LPPM Universitas Gadjah Mada.

**REFERENCES**

[1] C. E. Stockwell, T. Jayarathne, M. A. Cochrane, K. C. Ryan, E. I. Putra, B. H. Saharjo, A. D. Nurhayati, I. Albar, D. R. Blake, I. J. Simpson, E. A. Stone and R. J. Yokelson, "Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia, during the 2015 El Niño," *Atmospheric Chemistry and Physics*, vol. 16, pp. 11711 - 11732, 2016.

[2] S. E. Page, F. Siegert, J. O. Rieley, H. D. V. Boehm, A. Jaya and S. Limin, "The amount of carbon released from peat and forest fires in Indonesia during 1997," *Nature Publishing Group*, vol. 420, pp. 61 - 65, 2002.

[3] W. C. Adinugroho, I. N. N. Suryadiputra, B. H. Saharjo and L. Siboro, Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut, Bogor, Indonesia: Wetlands International – IP, 2004.

[4] H. Hayasaka, "Recent Large-Scale Fires in Boreal and Tropical Forests," *J. Disaster Res*, vol. 2, no. 4, pp. 265 - 275, 2007.

[5] S. R. Wahyunto, Suparto and H. Subagjo, Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan, Bogor, Indonesia: Proyek Climate Change, Forests and Peatlands in Indonesia-Wetlands International – Indonesia Programme dan Wildlife Habitat Canada, 2005.

[6] S. Ritung, Wahyunto, K. Nugroho, Sukarman, Hikmatullah, Suparto and C. Tafakresnanto, Peta Lahan Gambut Indonesia, Bogor: Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, 2011.

[7] H. Vasander, "Overview of types of peatland," in *Towards climate-responsible peatlands management*, Rome, Food and Agriculture Organization of the United Nation (FAO), 2014, pp. 15 - 18.

[8] S. W. Atmojo, Pengelolaan Lahan Gambut, Solo, Indonesia: UNS Press, 2014.

[9] S. Najiyati, L. Muslihat and I. N. N. Suryadiputra, Panduan Pengelolaan Lahan Gambut untuk Pertanian Berkelanjutan, Indonesia: Wetlands International - IP, 2005.

[10] I. T. C. Wibisono, L. Siboro and I. N. N. Suryadiputra, Panduan Rehabilitasi dan Teknik Silvikultur di Lahan Gambut, Bogor, Indonesia: Wetlands International - IP, 2005.

[11] J. Andriesse, Nature and Management of Tropical Peat Soils, Rome: FAO Soils Bulletins 59. Soil Resources, Management and Conservation Service FAO Land and Water Development Division. Food and Agriculture Organization of the United Nations, 1988.

[12] N. Yulianti and H. Hayasaka, "Recent Active Fires under El Niño Conditions in Kalimantan, Indonesia," *American Journal of Plant Sciences*, pp. 685 - 696, 2013.

[13] S. Page and A. Hooijer, "Environmental impacts and consequences of utilization peatlands," in *Towards Climate-responsible peatlands management*, R. Biancalani and A. Avagyan, Eds., Rome, Food and Agriculture Organization of the United Nations (FAO), 2014, pp. 27 - 35.

[14] P. Sofan, Y. Vetrita, F. Yulianto and M. R. Khomarudin, "Multi-temporal remote sensing data and spectral indices analysis for detection tropical rainforest degradation: case study in Kapuas Hulu and Sintang districts, West Kalimantan Indonesia," *Natural Hazard*, vol. 80, p. 1279–1301, 2016.

[15] K. Becek and A. B. Horwath, "Is vegetation collapse on Borneo already in progress?," *Natural Hazard*, vol. 85, pp. 1279 - 1290, 2017.

[16] H. Herawati and H. Santoso, "Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia," *Forest Policy and Economics*, pp. 227 - 233, 2011.

[17] A. C. Watts and L. N. Kobziar, "Smoldering Combustion and Ground Fires: Ecological Effects and Multi-Scale Significance," *Fire Ecology*, vol. 9, pp. 124 - 132, 2013.

[18] A. Sandhyavitri, R. Amri and D. Fermana, "Development of Underground Peat Fire Detections," Indonesia, 2016.

[19] X. Huang, F. Restuccia, M. Gramola and G. Rein, "Experimental study of the formation and collapse of an overhang in the lateral spread of smouldering peat fires," *Combustion and Flame*, vol. 168, p. 393–402, 2016.

[20] G. Rein, N. Cleaver, C. Ashton, P. Pironi and J. L. Torero, "The severity of smouldering peat fires and damage to the forest soil," *Catera,* vol. 74, pp. 304-309, 2008.

[21] M. G. L. Van Nieuwstadt and D. Sheil, "Drought, fire and tree survival in a Borneo rainforest, East Kalimantan, Indonesia," *Journal of Ecology,* vol. 93, pp. 191 - 201, 2005.

[22] S. Martin, M. Rodriguez, J. M. Moreno and D. G. Angeler, "Complex Ecological Responses to Drought and Fire-Retardant Contamination Impacts in Ephemeral Waters," *Water Air Soil Pollut,* vol. 225, pp. 1 - 13, 2014.

[23] M. Solh and M. van Ginkel, "Drought preparedness and drought mitigation in the developing world's drylands," *Weather and Climate Extremes,* vol. 3, pp. 62 - 66, 2014.

[24] R. S. Pulwarty and M. V. Sivakumar, "Information system in a changing climate: Early warnings and drought risk management," *Weather and Climate Extremes,* vol. 3, pp. 14 - 21, 2014.

[25] M. L. Khandekar, T. S. Murty, D. Scott and W. Baird, "The 1997 El Niño, Indonesian Forest Fires and the Malaysian Smoke Problem: A Deadly Combination of Natural and Man-Made Hazard," *Natural Hazard,* vol. 131–144, p. 21, 2000.

[26] R. D. Field, Y. Wang, O. Roswintiarti and Guswanto, "A drought-based predictor of recent haze events in western Indonesia," *E. A. International - Asia. Atmospheric Environment,* vol. 38, pp. 1869 - 1878, 2004.

[27] M. Pidwirny, "El Niño, La Niña and the Southern Oscillation. Fundamentals of Physical Geography, 2nd Edition," 2006. [Online]. Available: http://www.physicalgeography.net/fundamentals/7z.html. [Accessed 19 10 2015].

[28] N. Wanders, H. A. J. van Lanen and A. F. van Loon, "Indicators For drought characterization on a global scale," Technical Report No. 24. Hydrology and Quantitative Water Management Group (WUR). Wageningen University, Wageningen, 2010.

[29] A. Hasegawa, M. Gusyev and Y. Iwami, "Meteorological Drought and Flood Assesment Using the Comparative SPI Approach in Asia Under Climate change," *J. Disaster Res,* vol. 11, no. 6, pp. 1082 - 1090, 2016.

[30] D. A. Wilhite and M. D. Svaboda, "Drought Early Warning Systems in the Context of Drought Preparedness and Mitigation," National Drought Mitigation Center, Lincoln, Nebraska U.S.A, 2000.

[31] R. R. Heim, "A review of Twentieth-Century drought indices used in the United States," *Bulletin of the American Meteorological Society,* vol. 83, p. 1149 – 1165, 2002.

[32] H.-R. Byun and D. A. Wilhite, "Objective quantification of drought severity and duration," *Bulletin of the American Meteorological Society,* vol. 12, p. 2747 – 2756, 1999.

[33] D. X. Viegas, G. Bovio, A. Ferreira, A. Nosenzo and B. Sol, "Comparative study of various methods of fire danger evaluation in southern Europe," *International Journal of Wildland Fire,* vol. 9, pp. 235-246, 1999.

[34] P. Y. Groisman, R. W. Knight, D. R. Easterling, D. H. Levinson, R. R. Heim, T. R. Karl, P. H. whitfield, G. C. Hegerl, V. N. Razuavaev, B. G. Sherstyukov, J. G. Enloe and N. S. Stroumentova, "Changes in Precipitation Distribution Spectra and Contemporary Warming of the Extratropics: Implications for Intense Rainfall, Droughts, and Potential Forest Fire Danger," San Diago, 2005.

[35] C. Willis, B. van Wilgen, K. Tolhurst, C. Everson, P. D'Abreton, L. Pero and G. Fleming, The development of a national fire danger rating system for South Africa, Pretoria: Departement of water affairs and forestry, 2001.

[36] J. Skvarenina, J. Mindas, J. Holecy and a. Tucek, "Analysis of the natural and meteorological conditions during two largest forest fire events in the Slovak Paradise National Park," Athens, Greece, 2003.

[37] A. J. Dowdy, G. A. Mills, K. Finkele and W. de Groot, "Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index," CAWCR Technical Report No. 10, Australia, 2009.

[38] J. J. Keetch and G. M. Byram, "A drought index for forest fire control," *U.S. D. A Forest Service Research paper SE - 38,* vol. 38, pp. 1 - 31, 1968.

[39] G. Petros, M. Antonius and T. Marianthi, "Development of an adapted empirical drought index to the Mediterranean conditions for use in forestry," *Agricultural and Forest Meteorology,* vol. 151, p. 241–250, 2011.

[40] A. G. Prats, D. C. Antonio, T. Fernandes J. G and A. Molina J., "Development of a Keetch and Byram—Based drought index sensitive to forest management in Mediterranean conditions," *Agricultural and Forest Meteorology,* vol. 205, pp. 40 - 50, 2015.

[41] K. Dolling, P.-S. Chu and F. Fujioka, "A Climatological Study of Keetch/Byram Drought Index and Fire Activity in the Hawaiian Islands," *Agricultural and Forest Meteorology,* vol. 133, pp. 17 - 27, 2005.

[42] N. A. Ainuddin and J. Ampun, "Temporal Analysis of the Keetch-Byram Drought Index in Malaysia: Implications for Forest Fire Management," *Journal of Applied Sciences,* vol. 21, pp. 3991 - 3994, 2008.

[43] M. Taufik, B. I. Setiawan and H. A. J. Van Lanen, "Modification of a Fire Drought Index for Tropical Wetland Ecosystems by Including Water Table Depth," *Agricultural and Forest Meteorology,* vol. 203, p. 1 – 10, 2015.

[44] G. Buchholz and D. Weidemann, "The Used of Simple Fire Danger Rating System as a Tool for Early Warning in Forestry," IFFN, Samarinda, Indonesia, 2000.

[45] K. Kaku and A. Held, "International Journal of Disaster Risk Reduction," *Sentinel Asia: A space-based disaster management support system in the Asia - Pacific region,* vol. 6, pp. 1 - 17, 2013.

[46] E. I. Putra, H. Hayasaka, H. Takahashi and A. Usup, "Recent Peat Fire Activity in the Mega Rice Project Area, Central Kalimantan, Indonesia," *J. Disaster Res,* vol. 3, no. 5, pp. 334 - 341, 2008.

[47] P. P. R. PP No 71, "Perlindungan dan Pengelolaan Ekosistem Gambut," Pemerintah Republik Indonesia, Jakarta, 2014.

[48] P. P. R. PP No 57, "Perlindungan dan Pengelolaan Ekosistem Gambut," Pemerintah Republik Indonesia, Jakarta, 2016.

[49] T. Notohadiprawiro, "Mega-Project of Central Kalimantan Wetland Development for Food Crop Production, Belief and Truth," Jyvaskyla, 1998.

[50] H. Hayasaka, I. Noguchi, E. I. Putra, N. Yulianti and K. Vadrevu, "Peat-fire-related air pollution in Central Kalimantan, Indonesia," *Environmental Pollution,* vol. 195, pp. 257 - 266, 2014.

[51] N. Novitasari, J. Sujono, S. Harto, A. Maas and R. Jayadi, "Restoration of Peat Dome in Ex-Mega Rice Project Area in Central Kalimantan," in *Human-Dedicated Sustainable Product and Process Design: Material, Resources, and Energy: Proceedings of the 4th ICETIA 2017*, Surakarta, Indonesia, 2018.

[52] I. N. N. Suryadiputra, A. Dohong, R. S. B. Waspodo, L. Muslihat, I. R. Lubis, F. Hasudungan and I. T. C. Wibisono, Panduan Penyekatan Parit dan Saluran di Lahan Gambut Bersama Masyarakat, Bogor, Indonesia: Wetlands International - IP, 2005.

[53] J. Schmaltz and A. Voiland, "Earth Observatory," 2015. [Online]. Available: https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=86847. [Accessed 21 October 2016].

[54] D. Morton, R. DeFries, J. T. Randerson, L. Giglio, W. Schroeder and G. Van der Werf, "Agricultural intensification increases deforestation fire activity in Amazonia," *Global Change Biology,* vol. 14, pp. 2262-2276, 2008.

[55] KFCP, "Album Peta Rencana Pola Tata Guna Lahan Desa Sei Ahas," Kalimantan Forests and Climate Partnership (KFCP), Palangkaraya, 2014.

[56] H. Hayasaka, I. Noguchi, E. I. Putra, N. Yulianti and K. Vadrevu, "Peat Fire Related Air Pollution in Central Kalimantan, Indonesia," *Environmental Pollution,* vol. 195, pp. 257 - 266, 2014.

[57] W. C. Palmer, "Meteorological drought, research paper No. 45," Departement of Commerce, Washington D. C., 1965.

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari*1, Joko Sujono*1,†, Sri Harto*1, Azwar Maas*2, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

__X__ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Major comments:

Comment #1:

The repetitive text in Introduction, KBDI Index and some modifications, and Data sections in Lines 66-98, 154-196, 297-315, and 363-391 have similar information. The essential information should be greatly condensed to 1-2 sentences or moved to the discussion section. However, the introduction of various drought types is rather limited, see Line 114-127, and should be expanded especially in relation to groundwater levels. The authors should describe their drought using commonly drought terminology in peer-reviewed literature when referring to investigated drought types: meteorological (lack of precipitation), agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows) and socio-economic (lack of water supply to meet water demand) (Gusyev et al., 2015, 2016), which should be included. In addition, the authors could include WMO (2012; 2016) about various existing and new drought indices in Lines 128-153.

Comment #2:

The current structure of the manuscript has repetitive equations and text. Equation (1) is repeated by Equations (4)-(7), which have different coefficients of wc, a and b and should be removed. Instead, these coefficients should be given in new Table including computed evaporation time, t26.7, with annual rainfall values. Instead, the authors should add the formula of computing evaporation time. Therefore, I suggest to remove equations (4)-(7) by introducing values of coefficients in a new Table.

References:

Gusyev M.A., Hasegawa A., Magome J., Sanchez P., Sugiura A., Umino, H., Sawano H. and Y. Tokunaga (2016). Evaluation of water cycle components with standardized indices under climate change in the Pampanga, Solo and Chao Phraya basins. Journal of Disaster Research 11(6): 1091-1102, doi: 10.20965/jdr.2016.p1091

Gusyev M.A., Hasegawa A., Magome J., Kuribayashi D. and H. Sawano (2015). Drought assessment in the Pampanga River basin, the Philippines - Part 1: Characterizing a role of dams in historical droughts with standardized indices. In Weber, T., McPhee, M.J. and Anderssen, R.S. (eds) MODSIM2015, 21st International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2015: 1586-1592 pp. ISBN: 978-0-9872143-5-5.

World Meteorological Organization (WMO) (2012). Standardized Precipitation Index User Guide (M. Svoboda, M. Hayes, and D. Wood). WMO-No. 1090, Geneva.

World Meteorological Organization (WMO) (2016). Handbook of Drought Indicators and Indices. WMO-No. 1173, Geneva, 52 p.

<u>Minor comments:</u>

Line 40: Please clarify “other water table reference”?

Line 106: delete “Singapore”, which is not a country.

Lines 87-88: Do you fire? Smoke does not cause the loss of lifes and property.

Lines 114-127: see my major comment #1 to include all drought definitions.

Line 131: change “its impact” to “its impacts”

Line 134: Did you mean aridity index by Thornthwaite (1948)? Please include WMO (2012; 2017) references, see my comment #1.

Line 189: since it is now use, please remove the “WTF” acronym.

Ling 212 Equation 1: “ KBDIt = KBDIt +“ should be “KBDIt = KBDIt-1 + “

Line 238: Incorrect replace style and change to “[38]”

Line 255: Add reference [38].

Line 260: Remove “n” in “coefficient an”

Line 262: Incorrect style and change to “[38]”

Line 270: Incorrect style and change to “[43]”

Line 276: Incorrect style and change to “[38]”

Line 287: Incorrect style and change to “[43]”

Line 361: Re-name “Data” to “Study area and Data” Section

Line 362: Remove sub-section title.

Lines 392-411, Figure 1. Could you enlarge insets? It is very difficult to see details of canals.

Line 431: Remove sub-section title.

Line 448: Move “Methods” sub-section to “Methods” section.

Figure 2 & 3: This figures should be merged giving the same time-scale. Legends should be placed within figure

Line 673: References formatting is shifted and needs to be fixed to [].

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

_________ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

___○___ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Thank you for the paper discussing on KBDI and NFA relationships for mainly 2015.

My comment is as follows.

It is better to re-structure your paper. For example, you use 3. Data, 3.2 Data, 4.1 Rainfall Data, 4.2 Number of fire alerts data even the chapter 4 is Results and discussion.

Figure 2 and 3 ; Because we can know these figures for 2015, write horizontal axis simply.

Figure 3 and 4 ; Show vertical gridlines indicating months.

L207, 338 and 463 $\mathrm{R}_0$ -> $R_0$

L212 check equation (1).

L225 write as "5.1 mm/day"

L240 replace *x* with space, *a*. -> *a* and -0.001736.-> -0.001736

L260 coefficient *an* -> coefficient *a*

L265,285,293 and 345 $KBDI^{t-1}$ -> $KBDI_{t-1}$ replace *x* with space

L338 and 463 You wrote “$R_0$ =65” inches while you defined $R_0$ in mm/year in line 249.
L392-406 These pictures are very small and readers don’t find what you want to show.
L421-426 “This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke indicates the landfill condition [53]” looks to show the explanation of Figure 1.b. But I cannot find “red line” in Figure 1.b.
L461-463 You showed “annual rainfall of 1600 mm”. You discussed on the drought from September to November using 1600mm which include rainfall occurred after drought. Is it better take annual rainfall before dry season such as Oct to Sep?
L488 Show legend more clearly. Readers cannot distinguish them.
L587-588 You wrote “the extreme index level at the value of 375 and continues to rise to the maximum value of 400 starting on September 12, 2015 ”, but I cannot find 375 and 400 in Figure 3 and 4. Could you explain more about it.
L563 R0 -> $R_0$
L564-566 “high to extreme drought level was obtained starting from September to November 2015 as much as 51 indices” -> “extreme drought level was obtained starting from September to November 2015 as much as 51 indices”
L632-634 Could you explain from which you derived this knowledge.

Result and discussion ; Your analysis based on number of monthly events while you have daily base data. If you analyze in daily or weekly base, you may get more detail result.

Gmail

novitasari ST.,MT. <novitasari.st.mt@gmail.com>

# Fwd: Notification of receipt: Dr9565 Re: Notification of review result: Dr9565

**Joko Sujono** <jsujono@ugm.ac.id> 16 Juli 2019 pukul 11.44
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Tue, 16 Jul 2019 at 10:39
Subject: Notification of receipt: Dr9565 Re: Notification of review result: Dr9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Thank you for submitting the revised version of your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi.

Your paper has been sent to the corresponding reviewers.
You will be notified as soon as we receive the re-review results.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
-----------------------------------------------------------------------------------

On 2019/07/16 9:28, Joko Sujono wrote:

> Dear Aya Kamata
> JDR Editorial Office
>
> Herewith enclosed the revised paper " Drought Index for Peatland
> Wildfire Management in Central Kalimantan,
> Indonesia during El Niño Phenomeno" and the answer sheet for reviewers.
> Thank you very much for your kindness.
>
> Best regards,
> joko sujono
>
> On Tue, 25 Jun 2019 at 10:02, JDR Editorial Office
> <disaster@fujipress.jp <mailto:disaster@fujipress.jp>> wrote:
>
> Dear Dr. Joko Sujono,
>
> We have just received the reports on your paper entitled
>
> Drought Index for Peatland Wildfire Management in Central Kalimantan,
> Indonesia during El Niño Phenomenon
> by
> Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad
> Jayadi
>
> In view of the reviewers' comments,
> some changes are necessary for acceptance.
> Please revise your manuscript based on the attached
> reviewers' comments and send it to us by **July 16**.
>
> Please note that revised sentences should be indicated by color
> characters or color highlights in the revised manuscript.
>
> We look forward to receiving your answer to reviewers
> and revised manuscript (electronic file).
>
>
> Thank you
>
> Sincerely yours,
>
> Aya Kamata
> JDR Editorial Office
>
> Fuji Technology Press Ltd.
>
> Unizo Uchikanda 1-Chome Bldg. 2F
> 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> Phone: +81-3-5577-3851
> Fax: +81-3-5577-3861
> E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>

> ------------------------------------------------------------------------------------

>

UGM Mail

Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

# Fwd: Notification of review result: Dr9565

**Joko Sujono** <jsujono@ugm.ac.id> Tue, Jun 25, 2019 at 11:28 AM
To: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Tue, 25 Jun 2019, 10:02
Subject: Notification of review result: Dr9565
To: <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

We have just received the reports on your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

In view of the reviewers' comments,
some changes are necessary for acceptance.
Please revise your manuscript based on the attached
reviewers' comments and send it to us by **July 16**.

Please note that revised sentences should be indicated by color
characters or color highlights in the revised manuscript.

We look forward to receiving your answer to reviewers
and revised manuscript (electronic file).

Thank you

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to
SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts

published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
--------------------------------------------------------------------------------

---

**3 attachments**

**Cover_responsepage.docx**
17K

**jdr_reviewform_a2.pdf**
44K

**jdr_reviewform_b2.pdf**
122K

# Journal of Disaster Research (JDR) Review form

Title of paper: Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

___X___ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

I thank for the opportunity to review the revised manuscript by Noitsasari et al. "Drought Index for Peatland Wildfires Management in Central Kalimantan, Indonesia, El Nino Phenomenon". Although the authors address my previous comments, the English grammar and readability still need to be improved. In addition, I identified one critical concern regarding time calculation in the revised manuscript. My major and minor comments are listed below.

Critical concern:

I found the fundamental error in the authors calculation presented in Lines 231-257 and 318-322 and suggest to remove the text. If the authors want to keep the text, these calculations need to be checked and recalculated.

In Line 235, the authors statement about time increment is incorrect and equation (4) description should be replaced by “The equation of evapotranspiration timelag t with daily maximum temperature ($T_m$) and annual average rainfall ($R_o$) as follows”, see the Keetch, J.J. and Byram, G.M. (1968). Drought Index for Forest Fire Control. Res. Pap. SE-38. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 35 p., https://www.srs.fs.usda.gov/pubs/rp/rp_se038.pdf

In Line 237-239, the authors reported 56.41 days obtained from Equation (4) while I obtain $t(T_{m,} R_o)$ =3212 days with $T_m$ = 26.7 $^oC$ and $w_c$ = 203 mm and this implies that authors' calculation in Lines 246-247, 255-256 and 319-321 are incorrect.

Minor comments:

Line 27: Replace “in” by “from”

Line 28: Add replace “extreme” by “extreme values of”

Line 34: Replace “fire” by “fire alerts”

Line 46: Rewrite “in Indonesia in 2015 is” by “of 2015 in Indonesia has been”

Line 48: Clarify “trace gases”

Lines 63-34: Remove the sentence “Organic materials …”

Line 70: Replace “and more” by “making it”

Lines 78-79: Remove sentence “The water table …”

Line 98: Replace “Drought” by “Natural drought”

Lines 131-134: Remove sentence – redundant

Lines 143-146: Remove sentence – this is incorrect definition of index.

Lines 170: Combine two sentence by replacing “… conditions proving …”

Line 173: Move to the previous paragraph.

Line 226: Replace “mm/year” by “mm”

Lines 235-257: Remove the text, see my critical comment above.

Line 272: Replace “This formula” by “These coefficients”

Line 346: Rename “Study area and Data” by “Study area and Methods”

Line 350: Replace “found” by recorded”

Line 412: Replace “to be opened” by “cutting”

Line 415: Replace “with” by “due to”

Line 488-494: Replace “the change in wc” by KDBI and RF of 2015 are shown”, because the wc is not shown in Figure 3.

Lines 495-506: Replace “data” by “values”.

Line 520: Replace “some fire points (NFA)” by the number of fire alerts (NFA)”

Line 522: Replace figure caption with “Keetch-Byram Drought Index (KDBI) values and number of fire alert".

Line 529: Add "Two important findings are:"

Line 567-571: Rewrite by making two sentences.

Line 610: What is "large landfill trend"?

Line 660: Remove "dominant"

Line 662: Remove "of drought index"

Line 664: Replace "wildfires" by "wildfire"

Line 671: Replace "land" by "land-use"

Line 629-646: Remove text as it is not a discussion and is redundant.

# Journal of Disaster Research (JDR) Review form

Title of paper ： Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

_________ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

___〇___ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Thank you for the paper discussing on KBDI and NFA relationships for mainly 2015.

My comments are as follows.

Your analysis is just for 2015 and fire alerts concentrate in August to October. I don't think that rainfall in November and December affects fire alerts in the preceding duration. Further, why do you set 1600 mm as $R_0$, while your definition of $R_0$ is average annual rainfall (mm/year)?

L202, You use $R_t$ without definition.

L217 replace period which showing multiplication with space or multiplication sign.

L237 equation (4) is for T in Fahrenheit.

L242 replace $x$ with space or multiplication sign.

L242 equation (5) is for rainfall in inches.

L250-255 You wrote "tropical annual rainfall ($R_0$) as 2500 mm/year" but equation in L255 is the result using 100 inches(2540 mm).

L252 203 -> 203 mm

L299 203 -> 203 mm

L301 in hundredths of a millimeter -> in millimeter

L316 What do you mean with “two”?

L327 and 330 Nino -> Niño

L339 You wrote “Equation (7)”, but I cannot find Equation (7).

L342 Table (3) -> Table 3

L405 I cannot find Canal E in figure which include two Canal Cs.

L516-520 It is difficult for me to understand this sentence. Could you explain easier.

L584-586 In this paper, you show just the relationship between KBDI modification and wildfires but not cause and effect.

L39-41 You show just a good relationship in 2015. You’d better write after checking another El Niño years.

UGM Mail

**Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>**

# Fwd: Notification of review result: Dr9565

**Joko Sujono** <jsujono@ugm.ac.id> Fri, Aug 16, 2019 at 2:03 PM
To: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Fri, 16 Aug 2019, 10:00
Subject: Notification of review result: Dr9565
To: jsujono@ugm.ac.id >> Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

We have just received the reports on your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan,
Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad
Jayadi

In view of the reviewers' comments,
some changes are necessary for acceptance.
Please revise your manuscript based on the attached
reviewers' comments and send it to us by **August 30**.

Please note that revised sentences should be indicated by color
characters or color highlights in the revised manuscript.

We look forward to receiving your answer to reviewers
and revised manuscript (electronic file).

*Referring to publications of the Journal of Disaster Research in your
paper is strongly recommended.
All papers of the Journal of Disaster Research can be freely searched
and download at
https://www.fujipress.jp/jdr/dr
Creat your account (free) on:
https://www.fujipress.jp/usces-member/?page=newmember

Thank you

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)

*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
-------------------------------------------------------------------------------------

**3 attachments**

**Cover_responsepage.docx**
17K

**jdr_reviewform_a3.pdf**
74K

**jdr_reviewform_b3.pdf**
116K

# Journal of Disaster Research (JDR) Review form

Title of paper: Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

___X___ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

The authors did a good job implementing minor comments and fixing grammatical errors that have improved the readability of the revised manuscript. However, I find that the Equations presented in section 2.1 are still not fixed. In Line 211, Equation (3) is adopted from Eq. (1) in [37] and the reference [43] should be changed to [37]. Equation (4) is missing a bracket in the denominator and the origin of this equation is unknown. On page 31 of [43], the equation is given as by an empirical relationship of daily potential evapotranspiration and daily temperature in degrees of Fahrenheit (see Equation (13) of [43]):

$$t_{T,50} = \frac{w_c}{.352 \exp(.0486T) - 3.015}$$

In Lines 235-245, the time step of 56.41 days and 24.54 days was estimated by [43] and equation (5) of this paper was adopted from Equation (16) of [43] in inches to mm:.

$$\frac{t_{T,R}}{t_{T,R_o}} = \frac{f_2(R_o)}{f_2(R)} = \frac{1 + 10.88 \exp(-.04409R)}{1 + 10.88 \exp(-.04409R_o)} \qquad (16)$$

These values should be referenced and modification in equation clearly stated.

In Lines 250-254, the time step of 49.9 days was estimated by [37] and not from equations (4) and (5) as claimed by the authors. The reference should also be provided.

In summary, I find that the lack of attention to details by authors makes the credibility of presented work questionable and the authors should carefully check previously published equations and newly estimated coefficients prior to publication.

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

_________ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

___○___ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

Thank you for the paper discussing on KBDI and NFA relationships for mainly 2015.
My comments are as follows.
Your analysis is just for 2015. Your definition of $R_0$ is average annual rainfall (mm/year). How many years annual rainfall data should be used for $R_0$.
After detailed analysis of 2015 alone, you concluded "Finally, based on this research, the modified DFt can be applied to the El Niño phenomenon"(L662-664). Readers cannot understand why you can say "the modified *DFt* can be applied to the El Niño phenomenon". You should show evidence, otherwise you cannot say above.

For any variate through the paper, you should use italic font.

You have changed parameters of $DFt$ from previous manuscript but Table 5 is the same as previous one. Is it OK.

Check arrangement of Table 5(November).

UGM Mail

**Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>**

# Fwd: Request for submission of your accepted paper Dr14-8-9565

**Joko Sujono** <jsujono@ugm.ac.id> Wed, Sep 4, 2019 at 7:27 PM
To: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>
Cc: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Wed, 4 Sep 2019, 17:23
Subject: Request for submission of your accepted paper Dr14-8-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

We are pleased to inform you that your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan,
Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad
Jayadi
Manuscript ID: Dr14-8-9565

has been accepted for publication in the
Journal of Disaster Research.
Your paper is scheduled to appear in Vol.14 No.8.

We would like to ask you to submit the final version of your paper
and required materials by September 11 following the attached instruction.

Your cooperation would be deeply appreciated.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to
SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts
published in IJAT for free by free registration (No registration fee is
required).
Registration can be made at :

URL: https://www.fujipress.jp/usces-member/?page=newmember
--------------------------------------------------------------------------------------

**4 attachments**

**jdr_finalinst.pdf**
48K

**jdr_reviewform_a4.pdf**
193K

**jdr_reviewform_b4.pdf**
44K

**AcceptanceLetter_9565.pdf**
192K

# Journal of Disaster Research (JDR) Review form

Title of paper: Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

___X___ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

_________ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS (Please use additional sheet if necessary)

The authors implemented requested changes and the revised manuscript is ready for publication after fixing grammatical errors, see attached pdf file with my edits.

wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall [43]. The Basic formula of $DF_t$ from Equation (18) of [43] is modified in Equation (4) of [37], and be re-written ~~in~~ $a$, $b$, and $c$ coefficients in Equation (10) of [45] as follows:

$$DF_t = (w_c - KBDI_{t-1}) \frac{(ae^{(b\,Tm+1.5552)} - c)\,10^{-3}}{1+10.88\,e^{(-0.001736\,R_0)}} \qquad (3)$$

where:

$DF_t$ = drought factor (mm)
$w_c$ = the corresponding field capacity of available water in the layer (mm)
$KBDI_{t-1}$ = moisture deficiency (KBDI at $t-1$)
$Tm$ = daily maximum air temperature (°C)
$t$ = time increment (day)
$R_0$ = average annual rainfall (mm)
$a$ and $c$ = coefficient influenced by the mean annual rainfall ($R_0$)
$b$ = coefficient influenced by evapotranspiration

Under sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm, the maximum temperature ($T_m$) is 26.67 °C, and the corresponding field capacity of available water in the layer ($w_c$) is 203 mm [43]. ~~Equation (13)~~ of [43] gives $t_{26.67;\ R0}$ = 56.41 days. If $R = \infty$ and $R_0$ = ~~270~~ mm for sub tropical climate, Equation (~~16~~) of [43] gives $t_{26.67,\ \infty} = 0.4545\ t_{26.67;\ 1270}$ = 25.64 days.

Reference [37] modified the drought-factor formula ($DF_t$) affected by tropical annual rainfall ($R_0$) as 2540 mm, $w_c$, and temperature used the same as [43] is 26.67$^0$C. $w_c$ is 203 mm. Reference [37] adjustment the constants $t_{26.67,\ \infty}$ for tropical wetland climate as $t_{26.67,\ \infty} = 0.8831\ t_{26.67;\ 2540}$ = 49.87 days.

The coefficient $a$, $b$, and c for the subtropical condition [43] and tropical condition [37] can be seen in Table 1.

Table 1. Climate variables and the coefficient drought factor

| Variable | Subtropical | Tropical |
|---|---|---|
| $T_m$ ($^0$C) | 26.67 | 26.67 |
| $R_0$ (mm) | 1270 | 2540 |
| $a$ | 0.9667 | 0.4982 |
| $b$ | 0.0875 | 0.0875 |
| $c$ | 8.30 | 4.27 |
| $w_c$ | 203 | 203 |

## 2.2 KBDI index modification in the tropical climate

### 2.2.1 KBDI index modification in tropical wetland

Reference [37] modified $DF_t$ affected not only by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients $a$ and $c$. It concluded that the loss of evapotranspiration in the tropical climate is higher than 15% relative to that in the sub-tropical climate; thus, the coefficient $b$ in Table 2 become 0.0905 [37]. These coefficients used as modification one in tropical wetland condition in this paper.

### 2.2.1 KBDI modified under tropical peatland followed by El Niño

The formula of $DF_t$ [Equation (3)] has been developed to represent the average rainfall conditions in wildfire risk control for tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by the El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, and the amount of rainfall is below the normal conditions [27]. In 2009, in the Southern part of Kalimantan shows low precipitation, which causes peatland drying and easy spread of fires [46]. Analysis of rainfall from three stations in the study area indicates that when El Niño happened in 2015, rainfall decreased by approximately 35% of the annual average rainfall in the tropical climate. The annual rainfall in 2015 at the study area was 1650 mm. The evaporation time for the same temperature used by [43] is 26.67$^0$C.

In addition to the changes in the coefficients $a$ and $c$ on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 mm of soil water available for evapotranspiration [43]. The $w_c$ value was on the scale from 0 to 203, where 0 shows no moisture depletion, and 203 indicate the highest depletion [37]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on peatland research in the Netherlands that 400 mm depth of reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire and reduction of groundwater level [47]. The Government Regulation of the Republic of Indonesia No. 71 of 2014 [48] on peat ecosystem protection and management of clause 23 point 3, that was revised into regulation No. 57 of 2016, stating that peat ecosystem with cultivation function could be damaging if water table depth is more than 400 mm below the peat surface [49]. So in El Niño modified in this paper, $R_o$ is set as 1650 mm, $T_m$ is 26.67 and $w_c$ is 400. Based on the above concept, adjustment constants from Equation (13) of [43] in tropical peatland gives $t_{26.67;\ 1650}$ = 111.17 days and from Equation (16) of [43] $t_{26.67,\ \infty}$ = ~~0.6175~~ $t_{26.67;\ 1650}$ = ~~68.65~~ days.

The decrease in rainfall affects the values of the coefficients $a$ and $c$ on $DF_t$ in Equation (3) for modification 1 in tropical wetland condition [37], and modification 2 in tropical peatland condition due to El Niño in 2015 can be seen in Table 2. The coefficient $b$ used is 0.0905 [37].

コメントの追加 [NN1]: a3: Line 211 Reference [37] for tropical condition and reference [45] for a, b and c coefficient

コメントの追加 [NN2]: a3: $t_{26.67;\ R0}$ from Equation (13) [43]

コメントの追加 [NN3]: a3: $t_{26.67,\ \infty}$ from Equation (16) [43]

コメントの追加 [NN4]: a3: $t_{26.67,\ \infty}$ for tropical condition from [37]

コメントの追加 [NN5]: a3: using Equation (13) and Equation (16) of [43]

# Journal of Disaster Research (JDR) Review form

Title of paper : Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

## Recommendations

___○___ ACCEPT provided that all typographic errors and minor recommendations are corrected in the final draft.

_________ CONDITIONALLY ACCEPT provided that minor revisions are made as indicated in the "Comments to Authors" on the next page.

_________ REVISE AND RESUBMIT "Comments to Authors" on the next page.

_________ REJECT THE PAPER (R) (Future submissions of this work to the Journal will be treated as substantially new papers. Depending on circumstances, the editors may choose to include previous reviews of the rejected paper in any subsequent review of revised versions.)

COMMENTS TO AUTHORS

Thank you for your correction.

I noticed that there still remain typographic errors.

1) Through the paper, Be careful to use Italic font for variate, such as $R_0$, $R$

2) L235 270 -> 1270

FUJI TECHNOLOGY PRESS LTD.
2F Unizo Uchikanda 1-Chome Bldg., 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Tel: +81-3-5577-3851 Fax: +81-3-5577-3861 https://www.fujipress.jp

Fuji Technology Press Ltd.
Unizo Uchikanda 1-Chome Bldg.
2F, 1-15-7 Uchikanda, Chiyoda-ku,
Tokyo 101-0047, Japan
TEL: +81-3-5577-3851
FAX: +81-3-5577-3861
E-mail: disaster@fujipress.jp

Dr. Joko Sujono
Department of Civil and Environmental
Engineering, Faculty of Engineering,
Universitas Gadjah Mada
IDN

Dear Dr. Joko Sujono:

We are pleased to inform you that your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

Manuscript ID: Dr14-8-9565
Received date: August 1, 2018
Accepted date: September 4, 2019

has been accepted for publication in the Journal of Disaster Research.
Your paper is scheduled to appear in Vol.14 No.8.
We would like to ask you to submit the final version of your paper and required materials by September 11, 2019 following the attached instruction.

Your cooperation would be deeply appreciated.
Thank you for choosing this journal as your publishing medium.

Sincerely yours,

JDR Editorial Office
Fuji Technology Press Ltd.

# Instruction for submission of the final manuscript

Fuji Technology Press Ltd.
JDR Editorial Office

Thank you very much for submitting your paper to the Journal of Disaster Research. We would like to ask you to send the following materials to us by E-mail.

1. Final manuscript submission form: electronic file
2. Page charge agreement and reprint order form: hardcopy or scanned file
3. Copyright transfer form: hardcopy or scanned file
4. Electronic file for paper manuscript (MSWord file with its PDF file, or TeX)
5. Figure files (WORD, JPG, TIFF or EPS format)
6. References (include in the paper manuscript)
7. Keywords (include in the paper manuscript)
8. Profile for each author (Electronic file)
9. Authors' photos (include in above profile)

   (Template files for 1,2,3,8 can be downloaded from our website at https://www.fujipress.jp/jdr/dr-authors/#materials)

E-mail: disaster@fujipress.jp

Address:
Fuji Technology Press Ltd.
Unizo Uchikanda 1-Chome Bldg. 2F.
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Tel: +81-3-5577-3851
Fax: +81-3-5577-3861

Gmail

novitasari ST.,MT. <novitasari.st.mt@gmail.com>

# Fwd: Request for submission of your accepted paper Dr14-8-9565

**Joko Sujono** <jsujono@ugm.ac.id> 4 September 2019 pukul 19.27
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>
Cc: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Wed, 4 Sep 2019, 17:23
Subject: Request for submission of your accepted paper Dr14-8-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

We are pleased to inform you that your paper entitled

Drought Index for Peatland Wildfire Management in Central Kalimantan,
Indonesia during El Niño Phenomenon
by
Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad
Jayadi
Manuscript ID: Dr14-8-9565

has been accepted for publication in the
Journal of Disaster Research.
Your paper is scheduled to appear in Vol.14 No.8.

We would like to ask you to submit the final version of your paper
and required materials by September 11 following the attached instruction.

Your cooperation would be deeply appreciated.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to
SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts
published in IJAT for free by free registration (No registration fee is
required).
Registration can be made at :

URL: https://www.fujipress.jp/usces-member/?page=newmember
------------------------------------------------------------------------------------------

**4 lampiran**

**jdr_finalinst.pdf**
48K

**jdr_reviewform_a4.pdf**
193K

**jdr_reviewform_b4.pdf**
44K

**AcceptanceLetter_9565.pdf**
192K

Gmail

novitasari ST.,MT. <novitasari.st.mt@gmail.com>

# Fwd: English proofreading/ahead of schedule possibility: Dr14-8-9565

**Joko Sujono** <jsujono@ugm.ac.id> 11 September 2019 pukul 10.24
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>, Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Wed, 11 Sep 2019 at 09:22
Subject: English proofreading/ahead of schedule possibility: Dr14-8-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Proofreading by a native speaker of your manuscript has been completed.
Please find the attached PDF and WORD files.
Corrections and strike-outs in blue indicate deletions,
while those in red indicate additions.

1. English Proofreading
Please note that proposed corrections are recommended and
that you are free to apply or not apply them as you see fit.
Please correct the Word file (.doc) for your original manuscript
based on the proofread one and return it to us by e-mail.
Please note that no further publication processing will occur
until this proof is returned.
There is no need to write an answer to each comment from the proofer,
since this is not a part of reviewing process.
Please note that only linguistics are acceptable at this stage,
and should not involve substantial changes to the manuscript.

2. Ahead of schedule possibility
The publication of your paper has been scheduled in the November issue
(No.8),
but, if your English checking and author-proofreading will be completed
by the next week, we can publish it on the October issue (No.7).
If you hope, could you send your English proofread manuscript until Sep. 15?

Your cooperation in the above regard would be deeply appreciated.

Best regards,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr

---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
------------------------------------------------------------------------------------

**2 lampiran**

**Dr14-8-9565_proofread.docx**
6178K

**Dr14-8-9565_proofread.pdf**
513K

Paper :[Dr14-8-9565, 4807 Words]

# Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

**Novitasari Novitasari[*1], Joko Sujono[*1,†], Sri Harto[*1], Azwar Maas[*2], and Rachmad Jayadi[*1]**

[*1] Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Jl. Grafika No 2, Yogyakarta, 55281, Indonesia
[†] *Corresponding author. Tel.: +62 274 545675; Fax: +62 274 545676, E-mail address: jsujono@ugm.ac.id*
[*2] Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Jl. Flora, Bulak Sumur, Yogyakarta, 55281, Indonesia

コメントの追加 [A1]: Thanks for providing this opportunity to assist you with this manuscript. I have edited the text for language, grammar, and improved clarity. As no formatting instructions were provided, I have not looked into this aspect. I have, however, ensured that the style used predominantly by you is consistently maintained throughout the manuscript. Please check your target journal's guidelines and ensure that you comply with all the recommended guidelines.
Should you have any concerns, please feel free to get back to me.
My best wishes for your success with the manuscript.

As per the instructions, the gray highlighted text has been excluded from the edit.

Please note that some parts of the paper required minimal changes. However, rest assured that I have carefully checked the entire manuscript.

**Peatland wildfires, especially in tropical ecosystems, are often due caused byto drought, and lead to have caused smoke and other related problems in all aspects of community life in Indonesia, especially in Central Kalimantan. Drought is worsened by the number of drying days in the dry season, known as the El Niño phenomenon, and the drainage system in a peatland. Additionally, dDrought decreases the water table and increases the probability of triggers occurrence of wildfires in a peatland areas. This research study aims to modify the numerical formula of the drought factor (*DF$_t$*) in the Keetch–Byram dDrought iIndex (KBDI) of based on tropical peatland wildfire conditions in Central Kalimantan during the El Niño phenomenon in 2015. Furthermore, it and to appliesy a revised peatland water table reference ofare about 400 mm below the ground surface, based on previous research and the Government regulation on peatland ecosystem protection and management in Indonesia. Theseis El Niño conditions causeddd a rain decline of approximatelyabout 35% rain decline in Block A, Ex-Mega Rice Project (EMRP), Mantangai sub-District, Kapuas District, Central Kalimantan Province. The modified KBDI is compared with the Number of Fire Alerts (NFA) by using NASA's Active Fire Data in 2015. The analysis results show demonstrate that the modified *DF$_t$* under tropical peatland conditions leads to an increase in the drought index value, beginningwhich begins on the driest daysthe predominant drying day betweenfrom July andto November 2015. The extreme value of the KBDI drought index increasesd from the high to the extreme index from September to November 2015, when as manyuch as 61 extreme drought indices became an indicators for peatland wildfire risk assessment. The extreme KBDI is is directly proportional to the NFA recorded during 2015, and the highest number of fire alerts occurred is observed forin October 2015, with as much as 1746 hot spots within 31 days and extreme drought indices from 27 drying days. Hence, thise modified formula is suitable for wildfire conditions on this peatland wildfire condition in Central Kalimantan. Overall, the modified *DF$_t$* could can be successfully applied to the El Niño phenomenon in 2015.**

**Keywords:** Keetch–Byram drought index, Number of Fire Alerts, El Niño, peatland water table reference, peatland wildfire

## 1. Introduction

The forest wildfires of 2015 werein Indonesia has been the largest wildfires in Indonesia for in the last ten years in terms of the amounts of trace gases, and aerosols released, which have been that had been monitored in several previous studies [1]. The severity of theseis wildfires wasis similar to the disaster that occurred in 1997 [2]. Forest wildfires in Indonesia not only occur in upland environments but also in wetlands [3]. These forest wildfires mainly occur in tropical peatlands [4]. Wildfires in tropical peatlands occupy an area equivalent to 10.8% of Indonesia's land area [5]. Among tropical countries, Indonesia has the largest area of tropical peatland, which is about approximately 14 million ha and is mainly foundspreads in Sumatra, Kalimantan, and Papua [6]. Indonesia's peatland is a part of the wider tropical peatland habitat in Southeast Asia [7]. Tropical peat comprises accumulated organic materials in a wetland ecosystem [8]. Tropical peat is formed in forests under wetland conditions with the production of large quantities of organic materials [9][10].

Indonesia's peatland has beenis developed by the building a drainage systems. Canals are intended to decrease the water table in the peatland. These canals are utilized to support the cultivation of crops, such as oil palm and acacia. The resulting decrease in the water table can cause the peat to become over-drained and therebyby makeing it flammable, thereby damaging the ecological balance and eliminating forest and peatland biodiversity [10]. Peatland is commonly burned by people to minimize production cost;, however,but this practice may cause uncontrolled peatland wildfires [11]. In addition to human-caused fires, peatland wildfires are caused by meteorological drought factors, such as a lack of rainfall and high evaporation rate [12]. Dry peatland, which is fundamentally unstable, will loses water from the pores of the soil, allowing oxygen to penetrate the pores and oxidize the peat through biological and chemical processes [13]. Peatland wildfires not only cause rainforest degradation [14] and affect biodiversity [15], but also release smoke and~~from~~ carbon emissions to the atmosphere; fire harms nearby communities~~the human body~~ and leads to the loss of lives and property [16]. Peatland wildfires slowly spread ~~slowly~~ through the surface, and those classified as ~~a~~ smoldering fires~~type~~ are absorbed by the subsurface and organic layers [17]. This type of fire is difficult to ~~be~~ detect~~ed~~ [18]. Smoldering wildfire causes the lateral spread of flames under different moisture and wind conditions [19] and creates strong smoke that spreads over extensive areas [20]. Drought and fires are important components for the assessment of the dynamics of tropical peat forests [21].

The risk of wildfires increases as~~due to~~ the ~~increased~~ frequency and duration of drought increases [22]. Natural drought is a condition that cannot be managed [23] and has affected millions of square kilometers of land in many areas, such as North America, West Africa, and East Asia [24]. In Indonesia, drought in peatlands ~~causes~~leads to ~~wildfires as~~ sub-surface wildfires all around the ecosystem. These wildfires cause smoke to spread to other countries, such as Malaysia [25]. Fires occur almost every year in Indonesia during the dry season. Wildfires usually occur between June and September and ~~will~~ intensify during El Niño [26]. El Niño is a natural phenomenon characterized by the warming of temperatures in the Pacific Ocean and causes drought in the Asian region [27]. El Niño decreases the amount of rainfall in Indonesia [16].

A situation with lower than average~~ess than normal~~ water availability due to climate variability may cause drought [28]. The limitations for drought have not yet been widely agreed upon, which~~. This shows~~ indicates that drought is a region specific event~~ in a region~~. However, there are several types of drought that can~~will be shown to~~ be used as ~~a~~ reference. A d~~D~~ecreased amount of rainfall is also one of the causes of drought, namely, meteorological drought [29]. This type of drought appears in various components of the hydrological cycle [30]. Drought is not only caused by meteorological factors (lack of precipitation), but also ~~can be caused~~ by agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows), and socio-economic (lack of water supply to meet water demand) factors [29] [31].

In Indonesia, meteorological drought is often accompanied by dry peatland caused by the decline in the water table and changes in the physical properties of peat due to the drainage system. Some fires are also caused by human activities, such as land clearing. The b~~B~~locking of~~the~~ canals can ~~be recommended to~~ reduce the degradation of peatlands to a larger ~~scale~~ extent [32]. Additionally, i~~I~~t can also help to maintain the water table [33] to prevent drought on peatlands.

The process by which d~~D~~rought leads to~~causes~~ wildfires i~~n~~s a complex process, and a drought index cannot be easily specified. No index can fully explain the complexity of drought and its impacts [34]. ~~Furthermore, the~~A drought index can be used as an indicator to determine the classification of the drought level of a particular region or area [28]. Many drought indices have been expanded to appraise the scale, type, and impact of drought [35]. Many drought indices are~~re build and~~ easy to build and ~~to~~ use, based on meteorology data, soil moisture, hydrology, and remote sensing [36]. One~~Some~~ formula that uses~~ed~~ meteorological data is the s~~S~~tandardized p~~P~~recipitation i~~I~~ndex (SPI) [29] and the Keetch–Byram d~~D~~rought i~~I~~ndex (KBDI) [37].

Some ~~of the~~ drought indices are built~~d~~ for ~~the~~ specific uses and environments~~case~~. In forestry, many drought indices are designed for fire risk assessment [38]. The most widely used drought indices are the Nesterov index, ~~the~~ Zhdanko index [39], ~~the~~ Angstrom i~~I~~ndex [40], ~~the~~ Baumgartner index [41], ~~the~~ McArthur forest fire danger index [42], and ~~the Keetch–Byram Drought Index (~~KBDI~~)~~ [43]. KBDI is one of the most widely used indices for forest fire ~~control~~ management under various climatic conditions [34] [2]. KBDI was first developed for forest fire ~~control~~ management in the sub-tropical Florida region in ~~the~~ USA [3]. KBDI was also developed to be suitable under Mediterranean conditions, providing accurate results for ~~in~~ forestry and fire risk management in Thessaloniki, Northern Greece [44]. Therefore, this study aims to test the behavior of KBDI, modified for peatland wildfires in Central Kalimantan under tropical climate conditions affected by the El Niño disaster in 2015, when~~.~~ the El Niño conditions caused a significant rainfall decline in most parts of Indonesia.

## 2. KBDI Index Modification

### 2.1 KBDI and wildfire risk assessment

KBDI was first introduced to manage forest fire control under a sub-tropical climate. This index represents the net effect of evapotranspiration and precipitation on cumulative moisture deficiency in deep duff or upper soil layers, and is related to the flammability of organic materials in the ground [43]. KBDI is applied to human activity-caused fire and sub-surface fire, and ~~. KBDI~~ is determined using Equation (1).

$$KBDI_t = KBDI_{t-1} + DF_t - RF_t, \quad (1)$$

where:

$DF_t$ = drought factor (mm)
$RF_t$ = rainfall factor (mm)
$t$ = time (day)

The value of the rainfall factor ($RF_t$) is determined ~~by~~ using meteorological data, in the form of annual rainfall and daily rainfall. An $RF_t$ of more than 5.1 mm/day is considered a reduction in the drought index and is determined ~~with~~ using the following equation [43].

コメントの追加 [A3]: When the same article (the, a, or an) applies to all the nouns in a series, the article need not be repeated before every noun. Repeating the article makes the sentence unnecessarily wordy.

コメントの追加 [A2]: Please check if this is in line with your intended meaning.

$$RF = \begin{cases} (R_t - 5.1), R_t \geq 5.1\ mm/day, 1st\ rainy\ day \\ R_t,\ R_{t-1} \geq 5.1\ mm/day, 2nd\ and\ the\ next\ rainy\ day, \\ 0,\ R_t < 5.1\ mm/day \end{cases} \quad (2)$$

where:
$R_t$ = daily rainfall at $t$
$R_{t-1}$ = daily rainfall at $t-1$

The d~~D~~rought factor ($DF_t$) was determined based on the basic theory of soil moisture degradation in the forest area ~~for fire control~~ by assuming the following: (1) the field capacity of the organic layer is ~~taken~~ considered as 203 mm of water in excess of moisture held by the layer at the wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall [43]. The b~~B~~asic formula of $DF_t$ from Equation (18) of [43] is modified with Reference [37] for tropical condition, and Reference [45] for the $a$, $b$, and $c$ coefficients as follows:

$$DF_t = (w_c - KBDI_{t-1}) \frac{\left(ae^{(b\,Tm+1.5552)} - c\right) 10^{-3}}{1+10.88\, e^{(-0.001736\, R_0)}}, \quad (3)$$

where:
$DF_t$ = drought factor (mm)
$w_c$ = ~~the~~ corresponding field capacity of available water in the layer (mm)
$KBDI_{t-1}$ = moisture deficiency (KBDI at $t-1$)
$Tm$ = daily maximum air temperature (°C)
$t$ = time increment (day)
$R_0$ = average annual rainfall (mm)
$a$ and $c$ = coefficient influenced by the mean annual rainfall ($R_0$)
$b$ = coefficient influenced by evapotranspiration

In a ~~Under~~ sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm, ~~the~~ maximum temperature ($T_m$) is 26.67 °C, and ~~the~~ corresponding field capacity of available water in the layer ($w_c$) is 203 mm [43]. $t_{26.67; R0}$ from Equation (13) of [43] gives $t_{26.67;\ R0}$ = 56.41 days. If $R = \infty$ and $R_0$ = 1270 mm for a subtropical climate, $t_{26.67,\ \infty}$ from Equation (16) of [43] gives $t_{26.67,\ \infty}$ = 0.4545 $t_{26.67;\ 1270}$ = 25.64 days.

Reference [37] modifies~~d~~ the drought-factor formula ($DF_t$) affected by tropical annual rainfall ($R_0$) as 2540 mm, $w_c$, and the temperature used is the same as that in [43], which is 26.67 °~~º~~C. $w_c$ is 203 mm. Reference [37] adjusts~~ment~~ the constants $t_{26.67,\ \infty}$ for a tropical condition from [37] as $t_{26.67,\ \infty}$ = 0.8831 $t_{26.67;\ 2540}$ = 49.87 days.

The coefficients $a$, $b$, and $c$ for the sub-tropical condition [43] and tropical condition [37] are listed ~~can be seen~~ in Table 1.

Table 1. Climate variables and the coefficient drought factor

| Variable | Subtropical | Tropical |
|---|---|---|
| $T_m$ (°~~º~~C) | 26.67 | 26.67 |
| $R_0$ (mm) | 1270 | 2540 |
| $a$ | 0.9667 | 0.4982 |
| $b$ | 0.0875 | 0.0875 |
| $c$ | 8.30 | 4.27 |
| $w_c$ | 203 | 203 |

### 2.2 KBDI index modification for~~in~~ the tropical climate

#### 2.2.1 KBDI index modification for~~in~~ tropical wetland

Reference [37] modified $DF_t$ is affected ~~not only~~ by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients $a$ and $c$. It was concluded that t~~It concluded that t~~he loss of evapotranspiration in the tropical climate is ~~higher than~~ 15% higher relative to that in the sub-tropical climate; thus, the coefficient $b$ in Table 2 become 0.0905 [37]. These coefficients are used as the modifications ~~one in~~ for the tropical wetland conditions in this paper.

#### 2.2.1 KBDI modified for~~under~~ tropical peatlands followed by El Niño

The formula of $DF_t$ [Equation (3)] has been developed to represent the average rainfall conditions for~~in~~ wildfire risk control in~~for~~ tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by the El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, as well a reduction in average rainfall~~nd the amount of rainfall is below the normal conditions~~ [27]. In 2009, ~~in~~ the Southern part of Kalimantan received~~shows~~ low precipitation, which caused~~s~~ peatland drying and the easy spread of fires [46]. Analysis of rainfall from three stations in the study area indicates that when El Niño ~~happened~~ occurred in 2015, rainfall decreased by approximately 35% from~~of~~ the annual average rainfall ~~in the tropical climate~~. The annual rainfall in 2015 at the study area was 1650 mm. The evaporation time for the same temperature used by [43] was~~is~~ 26.67 °~~º~~C.

In addition to the changes in the coefficients $a$ and $c$ on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 mm of the soil water available for evapotranspiration [43]. The $w_c$ value was on the scale from 0 to 203, where 0 ~~shows~~ denotes no moisture depletion, and 203 indicates the highest depletion [37]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on peatland research in the Netherlands that used a 400 mm depth for the ~~of~~ reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire frequency and the ~~and~~ reduction of groundwater level [47]. The Government Regulation

コメントの追加 [A5]: Please use the correct degree symbol.

コメントの追加 [A4]: I am unsure of the intended meaning. Please check if my revision conveys the intended meaning.

書式を変更: フォント : 斜体

of the Republic of Indonesia No. 71 of 2014 [48] on peat ecosystem protection and management, of clause 23 point 3, whichthat was revised into regulation No. 57 of 2016, statesing that peat ecosystems with a cultivation function could be damageding if the water table depth is more than 400 mm below the peat surface [49]. So Thus, for thein El Niño modificationsed in this paper, $R_o$ is set as 1650 mm, $T_m$ is 26.67, and $w_c$ is 400. Based on the above concept, adjustment constants using Equation (13) and Equation (16) of [43] in tropical peatland gives $t_{26.67; 1650}$ = 111.17 days and $t_{26.67, \infty}$ = 0.617 $t_{26.67; 1650}$ = 68.6 days.

The decrease in rainfall affects the values of the coefficients $a$ and $c$ on $DF_t$ in Equation (3) for modification 1 in (tropical wetland conditions [37].,) and modification 2 in (tropical peatland conditions due to El Niño) in 2015 can be seen in Table 2. The coefficient $b$ used is 0.0905 [37].

Table 2. Climate variables and the coefficient drought factor for tropical wetland and peatland condition

| Parameter | Tropical wetland | Tropical peatland due to El Niño |
|---|---|---|
| $T_m$ ($^0$C) | 26.67 | 26.67 |
| $R_0$ (mm) | 2540 | 1650 |
| a | 0.4982 | 0.3614 |
| b | 0.0905 | 0.0905 |
| c | 4.27 | 3.10 |
| $w_c$ | 203 | 400 |

In the previous study,, they used four fire danger classes were used, from 0 to 203 mm [37]. In the present study, the new value of $w_c$ causes a change in the KBDI classes. The water table ranges from 0 to 400 mm. The water table at 400 mm below the surface is considered to cause the maximum drought index and cause a potential fire risk in the peat ecosystem. A water table of 0 mm, where water is on the surface of the land, is expressed as an ideal peat condition that is always inundated. Based on the new $w_c$ value for the peatland condition, the value of the KBDI classes is corrected. Drought index classes are divided classified into four levels, as presented in Table 3.

Table 3. Drought index classes of KBDI modified for tropical peatland conditions

| classes | KBDI index | KBDI index in tropical peatland |
|---|---|---|
| low | 0 – 100 | 0 – 200 |
| moderate | 101-150 | 201-300 |
| high | 151-175 | 301-350 |
| extreme | >175 | >350 |

## 3. Study Area and Methods

### 3.1 Study area

The Mega Rice Project consists of one million hectares of peatland in Central Kalimantan and caused damage tod the tropical peat forest [50]. It caused the large wildfire in 2015. The highest number of fire alerts (NFA) was recorded on October 19, 2015. The conditions of peatland wildfires in Kalimantan captured by the Moderate Resolution Imaging SpectroRadiometer (MODIS) from the NASA Aqua satellite are presented illustrated in Figure 1. This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke signals the conditionsindicates the landfill condition [51].

The present study was conducted in Block A, the Ex-Mega Rice Project (EMRP) located in Mantangai sub-District, Kapuas District, Central Kalimantan Province, which is shown illustrated in Figure 2a [52]. Figure 2b showed depicts some post-wildfires conditions in the peatland around Block A inon November 2015. Thise area underwentgoes land clearing, which causeds the peatland to become dry and flammable. A dDrought index for peat wildfire risk assessment was evaluated under peat wildfires conditions in 2015.

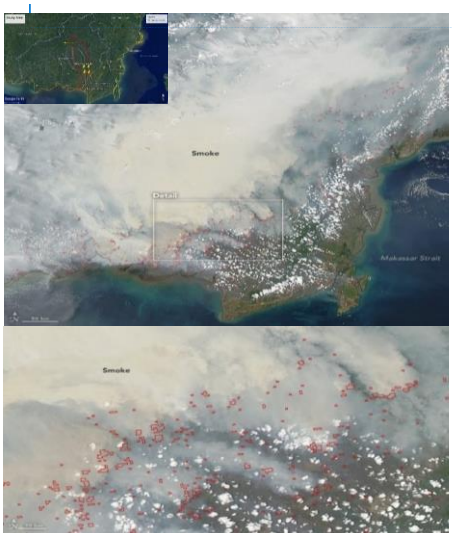
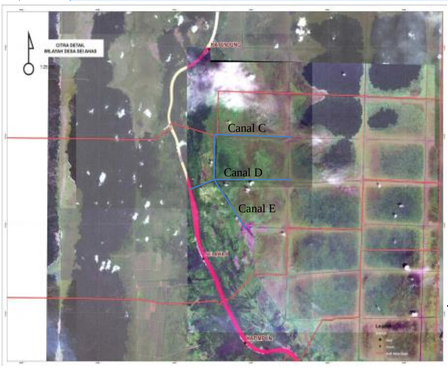



Figure 1. Wildfires hazard was found on October 19, 2015




コメントの追加 [A6]: If the first regulation has been superseded I would only state the most up to date regulation.

コメントの追加 [A7]: Something appears to be missing in this sentence. Please check.

コメントの追加 [A8]: Please consider increasing the text in the figure as it is not clearly legible.

コメントの追加 [A9]: Please note that all figures have been checked.


Figure 2. (a) Study area on Block A of Ex-Mega Rice Project and (b~~.~~) post-wildfire conditions in peatlands around canal C (b1), Canal D post-wildfire (b2), and Canal E post-wildfire (b3) in November 2015

The largest wildfires occur in tropical peatlands, including~~one of which is in~~ the tropical peatland in Indonesia. Peat wildfires have previously~~also~~ occurred in the EMRP area in Central Kalimantan [53]. The Mega Rice Project ~~was opened in~~ran from 1996 until 2009 and caused 400 thousand ha of tropical rainforest cutting. EMRP was~~is~~ a program that failed considerably~~ fails~~ to conserve the peatlands in Indonesia [50]. The exploitation of forest and peatland in EMRP land occurred~~s~~ due to the construction of drainage network~~s~~ systems [50]. The drainage network systems divide peat domes, causing massive damage and~~to peat dome,~~ resulting in their~~its~~ loss of function as field reservoirs, land subsidence, and a decreased water table [54]. This phenomenon causes irreversible ~~drying~~ peat drying, which triggers forest and peatland wildfires [55]. In addition to the decreased water table, peatland wildfires are ~~due~~ caused by~~to~~ the rainfall reduction (the number of dry~~ing~~ days), known as ~~due to~~ the El Niño phenomenon, which usually occurs from September to October.

Rainfall data was~~ere~~ recorded near the study area, such as in Tjilik Riwut, Beringin, and Sanggu Rain Station [56]. Rainfall data was~~ere~~ analyzed from 01 January 2015 to 31 December 2015, and there were a total of 263 dry days ~~were 263 days~~, which is~~are~~ more than 70% ~~from~~ of the total in 2015. The NFA in the form of hotspots were~~as~~ obtained by using NASA's Active Fire Data to determine the possible location of fires~~ on earth~~. The system uses NASA MODIS satellites, which survey the entire earth every 1–2 days. The sensors on these satellites detect hot marks in infrared spectral waves. During the processing of the satellite imagery, the algorithm looks for a heat sign and detects it as a fire sign. The system can indicate where a fire occurred and can ~~give~~ provide a warning of high risk areas [57].

### 3.2 Methods

In this study, a modified KBDI was developed for wildfire risk assessment under tropical peatland conditions influenced by El Niño,~~;~~ with modification to the baseline groundwater conditions for peatland affecting~~s~~ the $w_c$ value. The modified index was compared with KBDI under tropical wetland conditions [37]. The results of the two index modifications were compared against NFA recorded in the peat forest, Block A, Mantangai Sub-district, Central Kalimantan Province, i~~o~~n 2015.

## 4. Results and Discussion

### 4.1 Rainfall data

Based on the observations, rainfall from the three rain stations was~~is~~ almost uniform, with an average annual rainfall of 1650 mm in 2015. This rainfall value was~~is~~ below the average annual rainfall of areas with a~~the~~ tropical climate. The mean annual rainfall for areas with a~~under~~ tropical climate ranged~~s~~ from 2000 to 3000 mm [37]. Th~~is~~e decrease in rainfall was~~is~~ caused by the El Niño in Indonesia. The average monthly rainfall at the three stations in the study site was~~is~~ the highest (134 mm) i~~o~~n November 2015. The net rainfall or rainfall factor ($RF_t$) was~~is~~ calculated ~~with~~ using Equation (2) to determine the number of dry days (Table 4). Dry day conditions were found on~~in July as much as~~ 29 days in July, 28 days in August, 30 days in September and 27 days in October 2015.

### 4.2 Number of fire alerts data

~~NFA data during 2015 in Mantangai, Central Kalimantan.~~ I~~O~~n 2015,~~that year,~~ there were~~ NFA reaches as many as~~ 30,121 NFA events in the Central Kalimantan Province and 3,544 events in the Mantangai Sub-d~~sub D~~istrict. There were ~~NFA event in Mantangai is~~ 3525 NFA events~~nts~~ in Mantangai from July to November 2015, as much as 12.1% from the 29171 events in Central Kalimantan. NFA~~ began to~~ increased from July to November 2015, and the largest number of NFA was observed in October 2015, with~~ is as many as~~ 1741 events. Th~~is~~ese data ~~show~~indicates that the number of hotspots in October represents half of the NFA for~~over~~ the year 2015, as presented i~~. It is shown i~~n Table 4.

Table 4. Number of dry day and fire alerts

| | Number of the dry day | Number of fire alerts |
|---|---|---|
| Jan | 9 | 1 |
| Feb | 26 | 0 |
| Mar | 17 | 0 |
| Apr | 17 | 3 |
| May | 23 | 1 |
| Jun | 21 | 1 |
| Jul | 29 | 19 |
| Aug | 28 | 488 |
| Sep | 30 | 1272 |
| Oct | 27 | 1746 |
| Nov | 18 | 10 |
| Dec | 16 | 3 |

### 4.3 Keetch-Byram Drought Index (KBDI) analysis

T~~Based on t~~he results of the analysis using $DF_t$, under tropical wetland conditions [37] and under tropical peatland conditions influenced by the El Niño phenomenon are~~is~~ ~~shown~~ depicted in Figure 3.

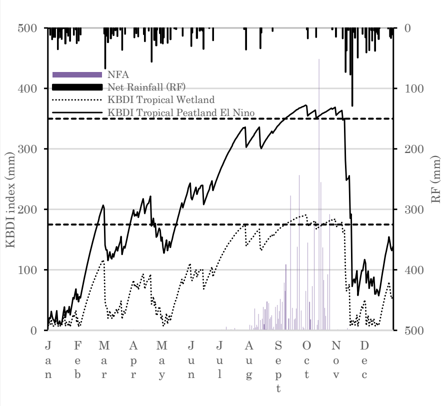



Figure 3. Comparison of KBDI for tropical wetland and the modified KBDI for~~of~~ tropical peatland with ~~due to~~ the El Niño phenomenon

~~In~~ Figure 3 depicts an~~, It~~ added ~~a~~ line for the beginning of the extreme index, at 175 mm for KBDI modified for the tropical wetland condition, and at 350 mm for KBDI modified for tropical peatland conditions. The KBDI level, with $DF_t$ formula for~~under~~ tropical wetland conditions, for a ~~of~~ low index level from 0—100 was 218 values, the moderate index from 101—150 was 42 values, the high drought index from 151—175 was as much as 56 values, and the extreme drought index of~~that~~ more than 175 was 49 values. In the calculation of KBDI, with the modified $DF_t$ formula for~~under~~ tropical peatland conditions including~~, which was influenced by~~ El Niño phenomenon, ~~from high level~~ there were 59 values from the high level, and the~~to~~ extreme drought conditions increased to 61 occurrences, from~~which started in~~ July until November 2015. The class index is presented in Table 5.

Table 5. Drought level conditions

| | Wetland conditions | | | | Peatland conditions due to El Niño | | | |
|---|---|---|---|---|---|---|---|---|
| | Low | Mod | High | Extreme | Low | Mod | High | Extreme |
| Jan | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |
| Feb | 23 | 5 | 0 | 0 | 26 | 2 | 0 | 0 |
| Mar | 30 | 1 | 0 | 0 | 30 | 1 | 0 | 0 |
| Apr | 30 | 0 | 0 | 0 | 21 | 9 | 0 | 0 |
| May | 28 | 3 | 0 | 0 | 20 | 11 | 0 | 0 |
| Jun | 25 | 5 | 0 | 0 | 0 | 30 | 0 | 0 |
| Jul | 0 | 16 | 15 | 0 | 0 | 12 | 19 | 0 |
| Aug | 0 | 12 | 19 | 0 | 0 | 1 | 30 | 0 |
| Sep | 0 | 0 | 7 | 23 | 0 | 0 | 8 | 22 |
| Oct | 0 | 0 | 9 | 22 | 0 | 0 | 0 | 31 |
| Nov | 20 | 0 | 6 | 4 | 15 | 5 | 2 | 8 |
| Dec | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |

~~Based on~~Owing to the 35% reduction in rainfall occurring in the study area in 2015 due to El Niño, and the change in $w_c$ caused by groundwater table change, the extreme drought index increased. High and extreme class results~~es~~ started at~~in~~ the beginning of the dry season from July. In calculating KBDI, with $DF_t$ formula under tropical wetland conditions and tropical peatland conditions, high drought levels began to occur in early July 2015. Extreme drought levels began to occur in September 2015. Figure 4 shows the h~~H~~igh and extreme classes in KBDI response (with the formula for~~under~~ tropical wetland conditions shown as modification 1, and ~~with~~ KBDI with $DF_t$ under tropical peatland conditions including~~were affected by~~ El Niño as modification 2) against fire risk assessment represented by the number of fire alerts.~~ (NFA) shown in Figure 4.~~

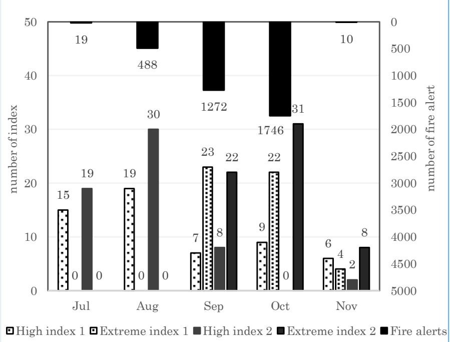



Figure 4. Correlation between Keetch-Byram d~~D~~rought i~~I~~ndex (KBDI) values and number of fire alerts (NFA)

Figure 4 shows the high and~~to the~~ extreme drought index results from the beginning of July to November 2015, representing the occurrence of ~~a starting point of~~ fires beginning in July 2015, from KBDI modification for~~under~~ tropical wetland and tropical peatland conditions. Two important findings are:

1. **Index response with the $DF_t$ formula for~~under~~ tropical wetland conditions**
   Based on the analysis of KBDI with the $DF_t$ formula for~~on~~ tropical wetland conditions, no extreme drought occurred at the beginning of July and August. Extreme drought indices occurred in September 2015 in~~as many as~~ 23 events, October 2015 in~~as many as~~ 22 events, and November 2015 in~~as much as~~ four events. Based on NFA data recorded in July,~~,~~ the study site had~~s~~ 19 hotspots, followed by ~~in August 2015 (~~488 hotspots in August)~~, and September 2015 (~~ 1272 hotspots in September,) and~~; most events as many as~~ 1746 hotspots ~~occurred~~ in October. The highest level of extreme index results~~x~~ occurred in September 2015 ~~as many as 23 days were not equal to the highest NFA in October 2015~~.
2. **KBDI response to a~~ds with~~ corrected $DF_t$ for~~under~~ tropical peatland conditions**
   In the corrected $DF_t$ formula for tropical peatland conditions affected by El Niño, with a rainfall reduction of 35% with $R_0$ = 1650 mm and groundwater level 400 mm, high to extreme drought levels were observed ~~was obtained starting~~

コメントの追加 [A11]: Please make the following changes
“Number of indices”
“Number of fire alerts”

コメントの追加 [A10]: Please check if this revision is in line with your intended meaning.

書式を変更: フォント : 太字

書式を変更: フォント : 太字

書式を変更: フォント : 太字

書式を変更: フォント : 太字

書式を変更: フォント : 太字

書式を変更: フォント : 太字

from September to ~~o~~ November 2015, ~~as much as~~with 61 indices. The results for the~~are~~ extreme drought index were~~of~~ 22 events in September, 31 events in October, and eight events in November 2015. This finding is consistent with the~~ presence of~~ NFA data, where the starting point of fire is in July and~~to~~ the highest number of hot~~fire~~ spots are in October, with ~~2015 as many as~~ 1746 hot spots. The~~o~~se hot spot conditions in October 2015 are predicted~~represented~~ by extreme drought conditions that cover the whole 31 days of the month.

### 4.4 Discussion

This study was conducted ~~arried out~~ on a peat fire situation in 2015 in Central Kalimantan. This study conducted analysis~~Based~~ on KBDI ~~analysis~~ results for data collected in~~in~~ 2015, comparing ~~between~~ corrected $DF_t$ modifications for~~under~~ tropical wetland conditions and tropical peatland conditions and ~~compared with~~ the number of fire alerts in Mantangai S~~s~~ub-d~~D~~istrict, with the~~the~~ results ~~show~~ demonstrating that:

1. The ~~faster~~ modifications of the~~response of~~ KBDI ~~modification~~ index for~~under~~ tropical peatland conditions adequately represents the real fire risk assessment data recorded in 2015. KBDI modification for~~under~~ tropical peatland conditions increases from the high index level to the extreme index level to~~at~~ the value of 350 and continues to rise to the maximum value of 400 starting on September 9, 2015, representing 109 NFA events that days ~~of as much as 109 events that day~~. KBDI modification for~~under~~ tropical wetland conditions increased~~s~~ from the high index level to the extreme index level on September 9, 2015, ~~with only~~ represented by 65 hot spots. These ~~extreme level of~~ modifications of the KBDI for~~under~~ the conditions of tropical peatlands can demonstrate ~~show~~ the potential for fire disasters in the study area.
2. In October 2015, there were 1746 NFA events in Mantangai, ~~were as many as 1746 events~~ with the KBDI modification for~~under~~ tropical peatland conditions resulting in~~shown by~~ 31 days of extreme indices, while the~~in~~ KBDI wetland modification only ~~indicated by~~resulted in 22 days with extreme indices. According to the modified $DF_t$ for~~under~~ tropical peatland conditions, the extreme classes~~es~~ is 12 points higher than KBDI modified for tropical wetland conditions. It rises from September to November 2015 in the study area, with the corrected water table of~~into~~ 400 mm.
3. The highest number of NFA was o~~i~~n October 14, 2015, with~~as many as~~ 449 hotspot events represented by the extreme value in KBDI modified for tropical peatland conditions,~~,~~ while ~~in~~ the KBDI modified for wetland conditions only resulted in~~represented by~~ high index results, as shown in Figure 3.
4. T~~Based on t~~he statistical parameter for extreme classes compared against the number of fires from July to November using linear regression for modification 1 gave~~have~~ $R^2$ as 0.828 with p-value 0.03. Modification 2 for~~under~~ tropical peatlands ~~formula,~~gave $R^2$ as 0.829 with p-value 0.03. ~~–~~It has been shown that both modifications ~~ed~~ give a good statistical result.

The m~~M~~odified KBDI ~~under~~for tropical peatland conditions seems to perform better in wildfire risk assessment in the Central Kalimantan during El Niño in 2015 compared with other KBDI formulas. The results ~~are~~ following ~~with~~ those of previous Kalimantan Forests and Climate Partnership (KFCP) observations. A~~Based on a~~ study by~~of~~ KFCP from 2004 to 2013 in the same study area showed~~,~~ daily wildfire patterns~~s~~ indicating~~ed~~ fires at the same locations and in the same months. Fires occurred ~~in~~ from late July t~~to~~ early November. The peak of the fires occurred in September [52]. Previous research from 2001 to 2010 found~~showed~~ large-scale land management practices using~~with~~ fire, which caused smoke hazards from mid-August to late October [53]. ~~Thus, by consideration~~We can consider the use of the empirical drought index formula for~~under~~ tropical peatland conditions to have several general principles, which ~~about the use of any empirical drought indices~~ are as follows~~:~~:

1. The KBDI formula ~~should~~ must be based on the net rainfall factor set by the R threshold. This threshold for tropical conditions still uses the same threshold as in the previous KBDI formula defined under sub-tropical conditions.
2. Peatland wildfires are not just caused by meteorological conditions but also by many internal factors in the soil, such as peat decomposition, physical properties, water holding capacity [33], and capillarity rise.
3. Peatland wildfires are also affected by unwise peatland ~~unwise~~ management, such as~~imilar to~~ building drainage canals in the peat dome, which results in a ~~that~~ change ins the water table.

Evaluation of the performance of KBDI under a range of~~some~~ climatic conditions, ~~ranging~~ including~~from~~ a sub-tropical climate, Mediterranean climate, and tropical climate, reports that KBDI is a flexible drought index for almost all climatic conditions and may represent an important tool for forest fire control.

## 5. Conclusion

KBDI modification, by correcting the $DF_t$ formula for~~against~~ the referenced water table level for peatland and with the influence of~~ed by~~ rainfall reduction due to the El Niño phenomenon, ~~in 2015~~ can accurately represent NFA in peatland. The analysis ~~results~~ shows the results~~behavior~~ of the KBDI; ~~of~~ drought correction ($DF_t$) for~~under~~ tropical peatland conditions, ~~already~~ gave an~~represented by~~ extreme index ~~from~~ (375 to 400

コメントの追加 [A12]: There is a lot of changing between the terms 'NFA' and 'hot spot'. It would be better to make this more consistent.

mm) occurring~~ed~~ from September 9, 2015. Twenty-seven dry days caused 31 days of extreme index, represented by~~as many as~~ 1746 hotspots in October 2015. The highest NFA number was o~~i~~n October 14, 2015 with~~as many as~~ 449 hotspot events represented ~~better~~ with this formula as an extreme value. Therefore, t~~Although t~~his formula provided satisfactory results in the El Niño conditions of~~in~~ 2015. Further testing is still needed to prove the formula for other El Niño events~~cases~~. ~~-~~In addition to the meteorological and water table factors in the KBDI formula, ~~that~~ which affect drought management in peatland, several supporting factors must be considered, such as peat decomposition, physical characteristics, water holding capacity, and capillarity rise. The degraded~~lower~~ physical properties of peatlands also lead to larger wildfires with the same number of dry~~ing~~ days.

**コメントの追加 [A13]:** Changes were made here to improve the clarity and readability of this part. Please check whether the revised part retains the intended meaning.

**Acknowledgments**

This study was completed with partial funding from Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) from the DRPM Ditjen Penguatan Riset dan Pengembangan, Ministry of Research, Technology, and High Education – the Republic of Indonesia through LPPM Universitas Gadjah Mada.

## 6. References

[1] C. E. Stockwell *dkk.*, "Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia, during the 2015 El Niño," *Atmos. Chem. Phys.*, vol. 16, no. 18, hal. 11711–11732, 2016.

[2] S. E. Page, F. Siegert, J. O. Rieley, H.-D. V. Boehm, A. Jaya, dan S. Limin, "The amount of carbon released from peat and forest fires in Indonesia during 1997," *Nature*, vol. 420, no. 6911, hal. 61–65, 2002.

[3] W. C. Adinugroho, I. N. N. Suryadiputra, B. H. Saharjo, dan L. Siboro, *Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut*. Bogor, Indonesia: Wetlands International - Indonesia Programme, 2004.

[4] H. Hayasaka, "Recent Large-Scale Fires in Boreal and Tropical Forests," *J. Disaster Res.*, vol. 2, no. 4, hal. 265–275, 2007.

[5] Wahyunto, S. Ritung, Suparto, dan H. Subagjo, *Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan*. Bogor, Indonesia: Wetlands International - Indonesia Programme, 2005.

[6] S. Ritung *dkk.*, *Peta Lahan Gambut Indonesia Skala 1:250.000*. 2011.

[7] H. Vasander, "3 . Overview of types of peatlands," dalam *Towards climate-responsible peatlands management*, Riccardo Biancalani and Armine Avagyan, Ed. Rome: Food and Agiculture Organization of the United Nations (FAO), 2014, hal. 15–18.

[8] S. W. Atmojo, *Pengelolaan Lahan Gambut*. Solo, Indonesia: UNS Press, 2014.

[9] S. Najiyati, L. Muslihat, I. Nyoman, dan N. Suryadiputra, *Panduan Pengelolaan Lahan Gambut*. Bogor, Indonesia: Wetlands International - Indonesia Programme, 2005.

[10] I. T. C. Wibisono, L. Siboro, dan I. N. N. Suryadiputra, *Panduan Rehabilitasi dan Teknik Silvikultur di Lahan Gambut*. 2005.

[11] Andriesse J. P, "Nature and Management of Tropical Peat Soils," *FAO Soils Bull.*, 1988.

[12] N. Yulianti dan H. Hayasaka, "Recent Active Fires under El Niño Conditions in Kalimantan , Indonesia," vol. 2013, no. March, hal. 685–696, 2013.

[13] S. Page dan A. Hooijer, "6 . Environmental impacts and consequences of utilizing peatlands," no. Ipcc 2013, Riccardo Biancalani and Armine Avagyan, Ed. Rome: Food and Agiculture Organization of the United Nations (FAO), 2014, hal. 27–35.

[14] P. Sofan, Y. Vetrita, F. Yulianto, dan M. R. Khomarudin, "Multi-temporal remote sensing data and spectral indices analysis for detection tropical rainforest degradation: case study in Kapuas Hulu and Sintang districts, West Kalimantan, Indonesia," *Nat. Hazards*, vol. 80, no. 2, hal. 1279–1301, 2016.

[15] K. Becek dan A. B. Horwath, "Is vegetation collapse on Borneo already in progress?," *Nat. Hazards*, vol. 85, no. 2, hal. 1279–1290, 2017.

[16] H. Herawati dan H. Santoso, "Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia," *For. Policy Econ.*, vol. 13, no. 4, hal. 227–233, 2011.

[17] A. C. Watts dan L. N. Kobziar, "Smoldering Combustion in Organic Soils : Peat and Muck Fires in the Southeastern U . S .," *South. Fire Exch.*, 2012.

[18] A. Sandhyavitri, D. Fermana, dan R. Amri, "Development of Underground Peat Fire Detection," no. July, hal. 439–444, 2016.

[19] X. Huang, F. Restuccia, M. Gramola, dan G. Rein, "Experimental study of the formation and collapse of an overhang in the lateral spread of smouldering peat fires," *Combust. Flame*, vol. 168, hal. 393–402, 2016.

[20] G. Rein, N. Cleaver, C. Ashton, P. Pironi, dan J. L. Torero, "The severity of smouldering peat fires and damage to the forest soil," *Catena*, vol. 74, no. 3, hal. 304–309, 2008.

[21] M. G. L. V. A. N. Nieuwstadt dan D. Sheil, "rain forest , East in a Borneo Drought , fire and tree survival Indonesia Kalimantan ," *Society*, vol. 93, no. 1, hal. 191–201, 2005.

[22] S. Martín, M. Rodríguez, J. M. Moreno, dan D. G. Angeler, "Complex ecological responses to drought and fire-retardant contamination impacts in ephemeral waters," *Water. Air. Soil Pollut.*, vol. 225, no. 8, 2014.

[23] M. Solh dan M. Van Ginkel, "Drought preparedness and drought mitigation in the developing world's drylands," *Weather Clim. Extrem.*, vol. 3, hal. 62–66, 2014.

[24] R. S. Pulwarty dan M. V. K. Sivakumar, "Information systems in a changing climate: Early warnings and drought risk management," *Weather Clim. Extrem.*, vol. 3, hal. 14–21, 2014.

[25] M. L. Khandekar, T. S. Murty, D. Scott, dan W. Baird, "The 1997 El Nino, Indonesian Forest fires and

the Malaysian Smoke problem: A deadly combination of natural and man-made hazard," *Nat. Hazards*, vol. 21, no. 2–3, hal. 131–144, 2000.

[26] R. D. Field, Y. Wang, O. Roswintiarti, dan Guswanto, "A drought-based predictor of recent haze events in western Indonesia," *Atmos. Environ.*, vol. 38, no. 13, hal. 1869–1878, 2004.

[27] M. Pidwirny, "El Niño, La Niña and the Southern Oscillation," 2006.

[28] N. N. Wanders, H. A. J. J. van Lanen, dan A. F. van Loon, "Indicators for drought characterization on a global scale," no. 24, hal. 93, 2010.

[29] A. Hasegawa, M. Gusyev, dan Y. Iwami, "Meteorological drought and flood assessment using the comparative SPI approach in Asia under climate change," *J. Disaster Res.*, vol. 11, no. 6, hal. 1082–1090, 2016.

[30] D. a Wilhite dan M. D. Svoboda, "Drought early warning systems in the context of drought preparedness and mitigation," *Early Warn. Syst. drought Prep. drought Manag.*, hal. 1–21, 2000.

[31] M. A. Gusyev, A. Hasegawa, J. Magome, D. Kuribayashia, H. Sawanoa, dan S. Lee, "Drought assessment in the Pampanga River basin, the Philippines – Part 1: Characterizing a role of dams in historical droughts with standardized indices," *21st Int. Congr. Model. Simul.*, no. December, hal. 1586–1592, 2015.

[32] R. A. Adesiji, P. A. Adeoye, dan A. O. Gbadebo, "Review Article Effects of Water Table Fluctuations on Peatland-A Review," *Sch. J. Eng. Technol.*, vol. 2, no. 3C, hal. 482–487, 2014.

[33] N. Novitasari, J. Sujono, S. Harto, A. Maas, dan R. Jayadi, "Pengaruh Karakteristik Gambut Terdegradasi terhadap Kebakaran Lahan Gambut," vol. 3, no. April, hal. 347–351, 2018.

[34] R. R. Heim, "A review of twentieth-century drought indices used in the United States," *Bulletin of the American Meteorological Society*. 2002.

[35] H.-R. Byun dan D. A. Wilhite, "Objective Quantification of Drought Severity and Duration," 1999.

[36] M. D. Svoboda dan B. A. Fuchs, *Handbook of drought indicators and indices*, no. 1173. 2017.

[37] M. Taufik, B. I. Setiawan, dan H. a. J. van Lanen, "Modification of a fire drought index for tropical wetland ecosystems by including water table depth," *Agric. For. Meteorol.*, vol. 203, no. Fire Drought Index, hal. 1–10, 2015.

[38] D. X. Viegas, G. Bovio, A. Ferreira, A. Nosenzo, dan B. Sol, "Comparative study of various methods of fire danger evaluation in southern Europe," *Int. J. Wildl. Fire*, vol. 9, no. 4, hal. 235, 1999.

[39] P. . Groisman, R. . Knight, dan T. . Karl, "Changes in Precipitation Distribution Spectra and Contemporary Warming of the Extratropics: Implications for Intense Rainfall, Droughts, and Potential Forest Fire Danger," *Am. Meteorol. Soc.*, hal. 9–13, 2005.

[40] C. Willis *dkk.*, "The Development of a National Fire Danger Rating System for South Africa," no. July, hal. 1–89, 2001.

[41] J. Skvarenina, J. Mindas, J. Holecy, dan J. Tucek, "Analysis of the natural and meteorological conditions during two largest forest fire events in the Slovak Paradise National Park," *J. Meteorol.*, vol. 7, hal. 167–171, 2003.

[42] A. J. Dowdy, G. a Mills, K. Finkele, dan W. De Groot, *Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index*, no. 10. 2009.

[43] J. J. Keetch dan G. M. Byram, "A Drought Index for Forest Fire Control," 1968.

[44] G. Petros, M. Antonis, dan T. Marianthi, "Development of an adapted empirical drought index to the Mediterranean conditions for use in forestry," *Agric. For. Meteorol.*, vol. 151, no. 2, hal. 241–250, 2011.

[45] a. Garcia-Prats, D. C. Antonio, F. J. G. Tarcísio, dan M. J. Antonio, "Development of a Keetch and Byram—Based drought index sensitive to forest management in Mediterranean conditions," *Agric. For. Meteorol.*, vol. 205, hal. 40–50, 2015.

[46] K. Kaku dan A. Held, "Sentinel Asia: A space-based disaster management support system in the Asia-Pacific region," *Int. J. Disaster Risk Reduct.*, vol. 6, hal. 1–17, 2013.

[47] E. I. Putra, H. Takahashi, H. Hayasaka, dan A. Usup, "Recent Peat Fire Activity in the Mega Rice Project Area, Central Kalimantan, Indonesia," *J. Disaster Res.*, vol. 3, no. 5, hal. 334–341, 2008.

[48] PP No 71, "PP 71_2014 Gambut," 2014.

[49] PP No 57, *PP No 57 Tahun 2016 Tentang Perubahan PP No 71 Perlindungan dan pengelolaan ekosistem gambut*. 2016.

[50] T. Notohadiprawiro, "Mega-Project of Central Kalimantan Wetland Development for Food Crop Production," no. 2006, hal. 1–14, 1998.

[51] NASA, "Earth Observatory," *Earth Observatory*, 2015. [Daring]. Tersedia pada: https://earthobservatory.nasa.gov/images/86847/heavy-smoke-blankets-borneo.

[52] KFCP, *Peta Rencana Pola Tata Guna Lahan Desa Sei Ahas*. Indonesia: Indonesia-Australia Forest Carbon Partnership (IAFCP), 2014.

[53] H. Hayasaka, I. Noguchi, E. Indra, N. Yulianti, dan K. Vadrevu, "Peat- fi re-related air pollution in Central Kalimantan , Indonesia," *Environ. Pollut.*, vol. 195, hal. 257–266, 2014.

[54] N. Novitasari, J. Sujono, S. Harto, A. Maas, dan R. Jayadi, "Restoration of peat dome in ex-Mega rice project area in Central Kalimantan," *AIP Conf. Proc.*, vol. 1977, 2018.

[55] I. N. N. Suryadiputra *dkk.*, *2005 Buku_Suryadiputra_Panduan Penyekatan Parit (Indonesia)*. Bogor, Indonesia: Wetlands International - Indonesia Programme, 2005.

[56] BMKG, "Data Hujan Online," Jakarta, 2019.

[57] D. C. Morton, R. S. Defries, J. T. Randerson, L. Giglio, W. Schroeder, dan G. R. van der Werf,

“Agricultural intensification increases deforestation fire activity in Amazonia,” *Glob. Chang. Biol.*, 2008.

UGM Mail

**Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>**

# Fwd: [Deadline: Sep. 17] 1st proof of your paper Dr14-7-9565

**Joko Sujono** <jsujono@ugm.ac.id> Sun, Sep 15, 2019 at 9:55 PM
To: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>
Cc: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Sun, 15 Sep 2019, 15:40
Subject: [Deadline: Sep. 17] 1st proof of your paper Dr14-7-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

The proof of your article, to be published in
the Journal of Disaster Research
Vol.14 No.7, has been prepared.
Please download the PDF file from the following:

https://box.fujipress.com/index.php/s/wGLLF02aGX5JlKg

Please proof-read it and return your corrections.
Acceptable at this stage are corrections about layout,
spelling mistakes, wrong cross-references, and
mistakes or updating in references.

Please use Acrobat to edit the PDF file
by adding "post-it" type notes,
and return it via e-mail to disaster@fujipress.jp.
If this is not possible, please print out the PDF file
and write down the corrections and any other comments on it.
Then, send it to us by FAX (+81-3-5577-3861) or
scan it to create a PDF file and send it to us via e-mail.

If changes are minimal, you can alternatively return the corrections
via e-mail, explaining where they occur in the paper
(page number and line) and specifying both the old (wrong) version
and the correction.

==================
The following questions have arisen during the preparation
of your proof. Please answer them.

1. Resolution of Fig. 1 is low.
Please send a high-resolution image if you have.

2. At the 1st paragraph of Section 3.1, there are the words "the red
line" (in Fig.1), but the color can not be distinguished when printed in
black and white.
Please change other expression without colors, or apply color printing
(JPY21000 per printed page).
(The article PDF published online will be full color for free.)

3. Please inform us the accessed date of Ref.[50].

4. Please provide us detailed information of Refs.[27][39][40][49][55].
For example, a publisher if it's a book, a journal title if a journal

article, URL and an accessed date if a website.
==================

No further publication processing will occur until this proof is returned.
Please respond by **September 17** in order to publish it on October issue.

Please note that this is your last chance to modify your paper.
The corrected version will be sent to you before publication.

Thank you for your cooperation.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp
HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts published in IJAT for free by free registration (No registration fee is required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
--------------------------------------------------------------------------------------

p.s.
To view and print the PDF article you will need Acrobat Reader from Adobe. This program is freely available and can be downloaded from http://www.adobe.com/products/acrobat/readstep2.html.
To edit the PDF files, you need Acrobat which is not free.
Please consult the manual of Acrobat for how to edit the PDF documents.

UGM Mail

**Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>**

# Fwd: Final proof of your paper Dr14-7-9565 (3)

**Joko Sujono** <jsujono@ugm.ac.id> Wed, Sep 18, 2019 at 2:03 PM
To: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Wed, 18 Sep 2019 at 12:57
Subject: Re: Final proof of your paper Dr14-7-9565 (3)
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Now, your article is finally finalized for publication.
We appreciate all your help and cooperation.

The issue including this article will be published on October 1, 2019.
To be accurate, you can read it at past midnight 12am (Japan Standard Time) of October 1.

Thank you for your continued support.

Best regards.

Aya Kamata (Ms.)
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp

On 2019/09/18 14:20, Joko Sujono wrote:
> Dear Ms. Aya Kamata
> JDR Editorial Office
> Fuji Technology Press Ltd.
>
> I thank you for the proof read of my paper. I think the file is fine.
> I will pay the publication fee soon. When, the paper will be published
> online?
> Again, thank you for your help and your kindness.
> Best regards,
> joko sujono
>
> On Wed, 18 Sep 2019 at 12:03, JDR Editorial Office
> <disaster@fujipress.jp <mailto:disaster@fujipress.jp>> wrote:
>
> Dear Dr. Joko Sujono,
>
> Thanks for your correction.
> We have attached the proof of your paper Dr14-7-9565 to this e-mail.
> Now your corrections have been included.

>
> Please check it and return your corrections by tomorrow, if any.
> If no response is received from the author, the publisher
> will proceed by assuming that there are no further corrections to be
> made.
>
> Thank you for your cooperation.
>
> Aya Kamata (Ms.)
> JDR Editorial Office
>
> Fuji Technology Press Ltd.
>
> Unizo Uchikanda 1-Chome Bldg. 2F
> 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> Phone: +81-3-5577-3851
> Fax: +81-3-5577-3861
> E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>
>
>
> On 2019/09/18 13:46, Joko Sujono wrote:
> > Dear Aya Kamata San
> > JDR Editorial Office
> > Fuji Technology Press Ltd.
> >
> > Thank you very much for the fast reply of my email. I want to
> apologize
> > since, I found mistype at the Acknowledgements as corrected at
> the file
> > attached. I hope this is the final correction.
> > I thank you for your kindness.
> > Best regards,
> > joko sujono
> >
> > On Wed, 18 Sep 2019 at 08:37, JDR Editorial Office
> > <disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>> wrote:
> >
> > Dear Dr. Joko Sujono,
> >
> > Thank you for your prompt reply.
> >
> > We have attached the proof of your paper Dr14-7-9565 to this
> e-mail.
> > Now your corrections have been included.
> > Please check it and return your corrections, if any.
> >
> > Please respond by tomorrow (Sep. 19) even if you have no
> corrections.
> > If no response is received from the author, the publisher
> > will proceed by assuming that there are no further
> corrections to be
> > made.
> >
> > Thank you for your cooperation.
> >
> > Best regards,
> >
> >
> > Aya Kamata (Ms.)
> > JDR Editorial Office
> >
> > Fuji Technology Press Ltd.
> >
> > Unizo Uchikanda 1-Chome Bldg. 2F

> > 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> > Phone: +81-3-5577-3851
> > Fax: +81-3-5577-3861
> > E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>
> >
> >
> > On 2019/09/18 9:15, Joko Sujono wrote:
> > > Dear Aya Kamata
> > > JDR Editorial Office
> > >
> > > I thank you for the proof of my paper. There is some
> correction
> > > especially on the explanation of Eq.1,2, and 3 as well as the
> > axis color
> > > of Fig. 4 as given in the file attached.
> > > Thank you for your kindness and I am looking forward for the
> > final proof.
> > >
> > > Best regards,
> > > joko sujono
> > >
> > > On Tue, 17 Sep 2019 at 09:40, JDR Editorial Office
> > > <disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>> wrote:
> > >
> > > Dear Dr. Joko Sujono,
> > >
> > > Thank you very much for your prompt reply and hard work.
> > >
> > > We have attached the proof of your paper Dr14-7-9565
> and an
> > invoice to
> > > this e-mail.
> > > Now your corrections have been included.
> > > Please check it and return your corrections, if any.
> > >
> > > ==================
> > > > 2. At the 1st paragraph of Section 3.1, there
> are the
> > words
> > > "the red
> > > > line" (in Fig.1),
> > > -> dark shapes
> > > Thank you for your modification.
> > > However, this modification may be unsuitable for the
> online
> > > full-colored
> > > PDF.
> > > As I have no idea of suitable words for both situations,
> > > I suggest to left the first expression "the red line."
> > > I'm sorry for troubling you.
> > >
> > > > 4. Please provide us detailed information of
> > > Refs.[27][39][40][49][55].
> > > Thank you for your information.
> > > I have added further information to that you provided.
> > > ==================
> > >
> > > Please respond within TWO DAYS (by Sep 19) from receipt of
> > > this message even if you have no corrections.
> > > If no response is received from the author, the publisher
> > > will proceed by assuming that there are no further

> > corrections to be
> > > made.
> > >
> > > Thank you for your cooperation.
> > >
> > > Best regards,
> > >
> > > Aya Kamata
> > > JDR Editorial Office
> > >
> > > Fuji Technology Press Ltd.
> > >
> > > Unizo Uchikanda 1-Chome Bldg. 2F
> > > 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> > > Phone: +81-3-5577-3851
> > > Fax: +81-3-5577-3861
> > > E-mail: disaster@fujipress.jp
> <mailto:disaster@fujipress.jp> <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>
> > > HP[OPEN ACCESS Journal] URL:
> https://www.fujipress.jp/jdr/dr/
> > > *Create your account (free) for download full-texts
> for free at :
> > > https://www.fujipress.jp/usces-member/?page=newmember (free)
> > > *Latest issue: https://www.fujipress.jp/jdr/dr/
> > > *Call for papers:
> > https://www.fujipress.jp/category/cfp/?journal=jsstr
> > > --------------------Please cite JDR papers - JDR is now
> > applying to
> > > SCI--------------------
> > > *JDR is indexed in SCOPUS and Compendex (Ei)
> > > *JACIII, JRM, JDR are indexed in ESCI
> > > *JDR is an OPEN ACCESS journal and you can download
> the all
> > full-texts
> > > published in IJAT for free by free registration (No
> > registration fee is
> > > required).
> > > Registration can be made at :
> > > URL: https://www.fujipress.jp/usces-member/?page=newmember
> > >
> >
> --------------------------------------------------------------------------------
> > >
> > >
> > >
> > >
> > > On 2019/09/16 14:06, Joko Sujono wrote:
> > > > Dear Aya Kamata
> > > > JDR Editorial Office
> > > > Fuji Technology Press Ltd.
> > > >
> > > > I thank you for the PDF proof read and the comment.
> > > > I have made a correction on the PDF file and
> provide more high
> > > quality
> > > > file of Fig.1 as attached.
> > > > Thank you very much for your kindness.
> > > > Best regards,
> > > > joko sujono
> > > >
> > > > On Sun, 15 Sep 2019 at 15:40, JDR Editorial Office
> > > > <disaster@fujipress.jp

> <mailto:disaster@fujipress.jp> <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>
> > > <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp> <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>>> wrote:
> > > >
> > > > Dear Dr. Joko Sujono,
> > > >
> > > > The proof of your article, to be published in
> > > > the Journal of Disaster Research
> > > > Vol.14 No.7, has been prepared.
> > > > Please download the PDF file from the following:
> > > >
> > > > https://box.fujipress.com/index.php/s/wGLLF02aGX5JlKg
> > > >
> > > > Please proof-read it and return your corrections.
> > > > Acceptable at this stage are corrections about
> layout,
> > > > spelling mistakes, wrong cross-references, and
> > > > mistakes or updating in references.
> > > >
> > > > Please use Acrobat to edit the PDF file
> > > > by adding "post-it" type notes,
> > > > and return it via e-mail to
> disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>
> > > <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp> <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>>>
> > > > <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>>.
> > > > If this is not possible, please print out the
> PDF file
> > > > and write down the corrections and any other
> comments
> > on it.
> > > > Then, send it to us by FAX (+81-3-5577-3861) or
> > > > scan it to create a PDF file and send it to us
> via e-mail.
> > > >
> > > > If changes are minimal, you can alternatively
> return the
> > > corrections
> > > > via e-mail, explaining where they occur in the
> paper
> > > > (page number and line) and specifying both the
> old (wrong)
> > > version
> > > > and the correction.
> > > >
> > > > =================
> > > > The following questions have arisen during the
> preparation
> > > > of your proof. Please answer them.
> > > >
> > > > 1. Resolution of Fig. 1 is low.
> > > > Please send a high-resolution image if you have.
> > > >

> > > > 2. At the 1st paragraph of Section 3.1, there
> are the
> > words
> > > "the red
> > > > line" (in Fig.1), but the color can not be
> > distinguished when
> > > > printed in
> > > > black and white.
> > > > Please change other expression without colors, or
> > apply color
> > > printing
> > > > (JPY21000 per printed page).
> > > > (The article PDF published online will be full
> color
> > for free.)
> > > >
> > > > 3. Please inform us the accessed date of Ref.[50].
> > > >
> > > > 4. Please provide us detailed information of
> > > Refs.[27][39][40][49][55].
> > > > For example, a publisher if it's a book, a journal
> > title if a
> > > journal
> > > > article, URL and an accessed date if a website.
> > > > ==================
> > > >
> > > > No further publication processing will occur until
> > this proof is
> > > > returned.
> > > > Please respond by **September 17** in order to
> publish
> > it on
> > > October
> > > > issue.
> > > >
> > > > Please note that this is your last chance to modify
> > your paper.
> > > > The corrected version will be sent to you before
> > publication.
> > > >
> > > > Thank you for your cooperation.
> > > >
> > > > Sincerely yours,
> > > >
> > > > Aya Kamata
> > > > JDR Editorial Office
> > > >
> > > > Fuji Technology Press Ltd.
> > > >
> > > > Unizo Uchikanda 1-Chome Bldg. 2F
> > > > 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> > > > Phone: +81-3-5577-3851
> > > > Fax: +81-3-5577-3861
> > > > E-mail: disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>
> > > <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp> <mailto:disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>>>
> > > > HP[OPEN ACCESS Journal] URL:
> > https://www.fujipress.jp/jdr/dr/

> > > > *Create your account (free) for download full-texts
> > for free at :
> > > >
> https://www.fujipress.jp/usces-member/?page=newmember (free)
> > > > *Latest issue: https://www.fujipress.jp/jdr/dr/
> > > > *Call for papers:
> > > https://www.fujipress.jp/category/cfp/?journal=jsstr
> > > > ---------------------Please cite JDR papers -
> JDR is now
> > > applying to
> > > > SCI---------------------
> > > > *JDR is indexed in SCOPUS and Compendex (Ei)
> > > > *JACIII, JRM, JDR are indexed in ESCI
> > > > *JDR is an OPEN ACCESS journal and you can download
> > the all
> > > full-texts
> > > > published in IJAT for free by free registration (No
> > > registration fee is
> > > > required).
> > > > Registration can be made at :
> > > > URL:
> https://www.fujipress.jp/usces-member/?page=newmember
> > > >
> > >
> >
> -----------------------------------------------------------------------------------
> > > >
> > > >
> > > > p.s.
> > > > To view and print the PDF article you will need
> Acrobat
> > > Reader from
> > > > Adobe. This program is freely available and can be
> > downloaded
> > > from
> > > > http://www.adobe.com/products/acrobat/readstep2.html.
> > > > To edit the PDF files, you need Acrobat which
> is not free.
> > > > Please consult the manual of Acrobat for how to
> edit
> > the PDF
> > > documents.
> > > >
> > >
> >
>

Gmail

**novitasari ST.,MT. <novitasari.st.mt@gmail.com>**

# Fwd: [Deadline: Sep. 17] 1st proof of your paper Dr14-7-9565

**Joko Sujono** <jsujono@ugm.ac.id> 15 September 2019 pukul 21.55
Kepada: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>
Cc: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Sun, 15 Sep 2019, 15:40
Subject: [Deadline: Sep. 17] 1st proof of your paper Dr14-7-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

The proof of your article, to be published in
the Journal of Disaster Research
Vol.14 No.7, has been prepared.
Please download the PDF file from the following:

https://box.fujipress.com/index.php/s/wGLLF02aGX5JlKg

Please proof-read it and return your corrections.
Acceptable at this stage are corrections about layout,
spelling mistakes, wrong cross-references, and
mistakes or updating in references.

Please use Acrobat to edit the PDF file
by adding "post-it" type notes,
and return it via e-mail to disaster@fujipress.jp.
If this is not possible, please print out the PDF file
and write down the corrections and any other comments on it.
Then, send it to us by FAX (+81-3-5577-3861) or
scan it to create a PDF file and send it to us via e-mail.

If changes are minimal, you can alternatively return the corrections
via e-mail, explaining where they occur in the paper
(page number and line) and specifying both the old (wrong) version
and the correction.

==================
The following questions have arisen during the preparation
of your proof. Please answer them.

1. Resolution of Fig. 1 is low.
Please send a high-resolution image if you have.

2. At the 1st paragraph of Section 3.1, there are the words "the red
line" (in Fig.1), but the color can not be distinguished when printed in
black and white.
Please change other expression without colors, or apply color printing
(JPY21000 per printed page).
(The article PDF published online will be full color for free.)

3. Please inform us the accessed date of Ref.[50].

4. Please provide us detailed information of Refs.[27][39][40][49][55].
For example, a publisher if it's a book, a journal title if a journal

article, URL and an accessed date if a website.
==================

No further publication processing will occur until this proof is returned.
Please respond by **September 17** in order to publish it on October issue.

Please note that this is your last chance to modify your paper.
The corrected version will be sent to you before publication.

Thank you for your cooperation.

Sincerely yours,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp


p.s.
To view and print the PDF article you will need Acrobat Reader from
Adobe. This program is freely available and can be downloaded from
http://www.adobe.com/products/acrobat/readstep2.html.
To edit the PDF files, you need Acrobat which is not free.
Please consult the manual of Acrobat for how to edit the PDF documents.

Gmail novitasari ST.,MT. <novitasari.st.mt@gmail.com>

# Fwd: Final proof of your paper Dr14-7-9565

**Joko Sujono** <jsujono@ugm.ac.id> 18 September 2019 pukul 09.41
Kepada: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>
Cc: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Wed, 18 Sep 2019, 08:37
Subject: Final proof of your paper Dr14-7-9565
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Thank you for your prompt reply.

We have attached the proof of your paper Dr14-7-9565 to this e-mail.
Now your corrections have been included.
Please check it and return your corrections, if any.

Please respond by tomorrow (Sep. 19) even if you have no corrections.
If no response is received from the author, the publisher
will proceed by assuming that there are no further corrections to be made.

Thank you for your cooperation.

Best regards,

Aya Kamata (Ms.)
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp

On 2019/09/18 9:15, Joko Sujono wrote:
> Dear Aya Kamata
> JDR Editorial Office
>
> I thank you for the proof of my paper. There is some correction
> especially on the explanation of Eq.1,2, and 3 as well as the axis color
> of Fig. 4 as given in the file attached.
> Thank you for your kindness and I am looking forward for the final proof.
>
> Best regards,
> joko sujono
>
> On Tue, 17 Sep 2019 at 09:40, JDR Editorial Office
> <disaster@fujipress.jp <mailto:disaster@fujipress.jp>> wrote:
>
>     Dear Dr. Joko Sujono,

>
> Thank you very much for your prompt reply and hard work.
>
> We have attached the proof of your paper Dr14-7-9565 and an invoice to
> this e-mail.
> Now your corrections have been included.
> Please check it and return your corrections, if any.
>
> ==================
> > 2. At the 1st paragraph of Section 3.1, there are the words
> "the red
> > line" (in Fig.1),
> -> dark shapes
> Thank you for your modification.
> However, this modification may be unsuitable for the online
> full-colored
> PDF.
> As I have no idea of suitable words for both situations,
> I suggest to left the first expression "the red line."
> I'm sorry for troubling you.
>
> > 4. Please provide us detailed information of
> Refs.[27][39][40][49][55].
> Thank you for your information.
> I have added further information to that you provided.
> ==================
>
> Please respond within TWO DAYS (by Sep 19) from receipt of
> this message even if you have no corrections.
> If no response is received from the author, the publisher
> will proceed by assuming that there are no further corrections to be
> made.
>
> Thank you for your cooperation.
>
> Best regards,
>
> Aya Kamata
> JDR Editorial Office
>
> Fuji Technology Press Ltd.
>
> Unizo Uchikanda 1-Chome Bldg. 2F
> 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> Phone: +81-3-5577-3851
> Fax: +81-3-5577-3861
> E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>

>
>
>

>
> On 2019/09/16 14:06, Joko Sujono wrote:
> > Dear Aya Kamata
> > JDR Editorial Office
> > Fuji Technology Press Ltd.
> >
> > I thank you for the PDF proof read and the comment.
> > I have made a correction on the PDF file and provide more high
> quality
> > file of Fig.1 as attached.
> > Thank you very much for your kindness.
> > Best regards,
> > joko sujono
> >
> > On Sun, 15 Sep 2019 at 15:40, JDR Editorial Office
> > <disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>> wrote:
> >
> > Dear Dr. Joko Sujono,
> >
> > The proof of your article, to be published in
> > the Journal of Disaster Research
> > Vol.14 No.7, has been prepared.
> > Please download the PDF file from the following:
> >
> > https://box.fujipress.com/index.php/s/wGLLF02aGX5JlKg
> >
> > Please proof-read it and return your corrections.
> > Acceptable at this stage are corrections about layout,
> > spelling mistakes, wrong cross-references, and
> > mistakes or updating in references.
> >
> > Please use Acrobat to edit the PDF file
> > by adding "post-it" type notes,
> > and return it via e-mail to disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>
> > <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>.
> > If this is not possible, please print out the PDF file
> > and write down the corrections and any other comments on it.
> > Then, send it to us by FAX (+81-3-5577-3861) or
> > scan it to create a PDF file and send it to us via e-mail.
> >
> > If changes are minimal, you can alternatively return the
> corrections
> > via e-mail, explaining where they occur in the paper
> > (page number and line) and specifying both the old (wrong)
> version
> > and the correction.
> >
> > ==================
> > The following questions have arisen during the preparation
> > of your proof. Please answer them.
> >
> > 1. Resolution of Fig. 1 is low.
> > Please send a high-resolution image if you have.
> >
> > 2. At the 1st paragraph of Section 3.1, there are the words
> "the red
> > line" (in Fig.1), but the color can not be distinguished when
> > printed in
> > black and white.
> > Please change other expression without colors, or apply color
> printing
> > (JPY21000 per printed page).
> > (The article PDF published online will be full color for free.)

> > 
> > 3. Please inform us the accessed date of Ref.[50].
> > 
> > 4. Please provide us detailed information of
> Refs.[27][39][40][49][55].
> > For example, a publisher if it's a book, a journal title if a
> journal
> > article, URL and an accessed date if a website.
> > =================
> > 
> > No further publication processing will occur until this proof is
> > returned.
> > Please respond by **September 17** in order to publish it on
> October
> > issue.
> > 
> > Please note that this is your last chance to modify your paper.
> > The corrected version will be sent to you before publication.
> > 
> > Thank you for your cooperation.
> > 
> > Sincerely yours,
> > 

> > Aya Kamata
> > JDR Editorial Office
> > 
> > Fuji Technology Press Ltd.
> > 
> > Unizo Uchikanda 1-Chome Bldg. 2F
> > 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> > Phone: +81-3-5577-3851
> > Fax: +81-3-5577-3861
> > E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>
> <mailto:disaster@fujipress.jp <mailto:disaster@fujipress.jp>>


> > 
> > 
> > p.s.
> > To view and print the PDF article you will need Acrobat
> Reader from
> > Adobe. This program is freely available and can be downloaded
> from
> > http://www.adobe.com/products/acrobat/readstep2.html.
> > To edit the PDF files, you need Acrobat which is not free.
> > Please consult the manual of Acrobat for how to edit the PDF
> documents.

> >
>

**Dr14-7-9565.pdf**
3557K

Paper: Dr14-7-9565;

# Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia During El Niño Phenomenon

**Novitasari Novitasari**[*], **Joko Sujono**[*,†], **Sri Harto**[*], **Azwar Maas**[**], **and Rachmad Jayadi**[*]

[*]Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Jl. Grafika No 2, Yogyakarta 55281, Indonesia
[†]Corresponding author, E-mail: jsujono@ugm.ac.id
[**]Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia
[Received August 1, 2018; accepted September 4, 2019]

**Peatland wildfires, especially in tropical ecosystems, are often caused by drought, and lead to smoke and other related problems in all aspects of community life in Indonesia, especially in Central Kalimantan. Drought is worsened by the number of dry days in the dry season, known as the El Niño phenomenon, and the drainage system in a peatland. Additionally, drought decreases the water table and increases the probability of occurrence of wildfires in peatland areas. This study aims to modify the numerical formula of the drought factor ($DF_t$) in the Keetch–Byram drought index (KBDI) based on tropical peatland wildfire conditions in Central Kalimantan during the El Niño phenomenon in 2015. Furthermore, it applies a revised peatland water table reference of 400 mm below the ground surface, based on previous research and the Government regulation on peatland ecosystem protection and management in Indonesia. These El Niño conditions caused a rain decline of approximately 35% in Block A, Ex-Mega Rice Project, Mantangai sub-District, Kapuas District, Central Kalimantan Province. The modified KBDI is compared with the Number of Fire Alerts (NFA) using NASA's Active Fire Data in 2015. The analysis results demonstrate that the modified $DF_t$ under tropical peatland conditions leads to an increase in the drought index value, beginning on the driest days between July and November 2015. The value of the KBDI drought index increases from the high to the extreme index from September to November 2015, when as many as 61 extreme drought indices became indicators for peatland wildfire risk assessment. The extreme KBDI is directly proportional to the NFA recorded during 2015, and the highest number of fire alerts is observed for October 2015, with 1746 fire alerts within 31 days and extreme drought indices from 27 days. Hence, this modified formula is suitable for wildfire conditions on this peatland in Central Kalimantan. Overall, the modified $DF_t$ can be successfully applied to the El Niño phenomenon in 2015.**

**Keywords:** Keetch–Byram drought index (KBDI), number of fire alerts, El Niño, water table, peatland wildfire

## 1. Introduction

The forest wildfires of 2015 were the largest wildfires in Indonesia for the last ten years in terms of the amounts of trace gases and aerosols released, which have been monitored in several previous studies [1]. The severity of theses wildfires was similar to the disaster that occurred in 1997 [2]. Forest wildfires in Indonesia not only occur in upland environments but also in wetlands [3]. These forest wildfires mainly occur in tropical peatlands [4]. Wildfires in tropical peatlands occupy an area equivalent to 10.8% of Indonesia's land area [5]. Among tropical countries, Indonesia has the largest area of tropical peatland, which is approximately 14 million ha and is mainly found in Sumatra, Kalimantan, and Papua [6]. Indonesia's peatland is a part of the wider tropical peatland habitat in Southeast Asia [7]. Tropical peat comprises accumulated organic materials in a wetland ecosystem [8]. Tropical peat is formed in forests under wetland conditions with the production of large quantities of organic materials [9, 10].

Indonesia's peatland has been developed by the building drainage systems. Canals are intended to decrease the water table in the peatland. These canals are utilized to support the cultivation of crops, such as oil palm and acacia. The resulting decrease in the water table can cause the peat to become overdrained and thereby make it flammable, damaging the ecological balance and eliminating forest and peatland biodiversity [10]. Peatland is commonly burned to minimize production cost; however, this practice may cause uncontrolled peatland wildfires [11]. In addition to human-caused fires, peatland wildfires are caused by meteorological drought factors, such as a lack of rainfall and high evaporation rate [12]. Dry peatland, which is fundamentally unstable, loses water from the soil, allowing oxygen to penetrate the pores and oxidize the peat through biological and chemical processes [13]. Peatland wildfires not only cause rainforest degradation [14] and affect biodiversity [15], but also release smoke and carbon emissions to the atmosphere; fire harms nearby communities and leads to the loss of lives and property [16]. Peatland wildfires slowly spread through the surface, and those classified as smoldering fires are absorbed by the subsurface and organic lay-

ers [17]. This type of fire is difficult to detect [18]. Smoldering wildfire causes the lateral spread of flames under different moisture and wind conditions [19] and creates strong smoke that spreads over extensive areas [20]. Drought and fires are important components for the assessment of the dynamics of tropical peat forests [21].

The risk of wildfires increases as the frequency and duration of drought increases [22]. Natural drought is a condition that cannot be managed [23] and has affected millions of square kilometers of land in many areas, such as North America, West Africa, and East Asia [24]. In Indonesia, drought in peatlands leads to sub-surface wildfires all around the ecosystem. These wildfires cause smoke to spread to other countries, such as Malaysia [25]. Fires occur almost every year in Indonesia during the dry season. Wildfires usually occur between June and September and intensify during El Niño [26]. El Niño is a natural phenomenon characterized by the warming of temperatures in the Pacific Ocean and causes drought in the Asian region [27]. El Niño decreases the amount of rainfall in Indonesia [16].

A situation with lower than average water availability due to climate variability may cause drought [28]. The limitations for drought have not yet been widely agreed upon, which indicates that drought is a region specific event. However, there are several types of drought that can be used as reference. A decreased amount of rainfall is also one of the causes of drought, namely, meteorological drought [29]. This type of drought appears in various components of the hydrological cycle [30]. Drought is not only caused by meteorological factors (lack of precipitation), but also by agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows), and socio-economic (lack of water supply to meet water demand) factors [29, 31].

In Indonesia, meteorological drought is often accompanied by dry peatland caused by the decline in the water table and changes in the physical properties of peat due to the drainage system. Some fires are also caused by human activities, such as land clearing. The blocking of canals can reduce the degradation of peatlands to a larger extent [32]. Additionally, it can also help to maintain the water table [33] to prevent drought on peatlands.

The process by which drought leads to wildfires is a complex process, and a drought index cannot be easily specified. No index can fully explain the complexity of drought and its impacts [34]. A drought index can be used as an indicator to determine the classification of the drought level of a particular region or area [28]. Many drought indices have been expanded to appraise the scale, type, and impact of drought [35]. Many drought indices are easy to build and use, based on meteorology data, soil moisture, hydrology, and remote sensing [36]. One formula that uses meteorological data is the standardized precipitation index (SPI) [29] and the Keetch–Byram drought index (KBDI) [37].

Some drought indices are built for specific uses and environments. In forestry, many drought indices are designed for fire risk assessment [38]. The most widely used drought indices are the Nesterov index, Zhdanko index [39], Angstrom index [40], Baumgartner index [41], McArthur forest fire danger index [42], and KBDI [43]. KBDI is one of the most widely used indices for forest fire management under various climatic conditions [2, 34]. KBDI was first developed for forest fire management in the sub-tropical Florida region in USA [3]. KBDI was also developed to be suitable under Mediterranean conditions, providing accurate results for forestry and fire risk management in Thessaloniki, Northern Greece [44]. Therefore, this study aims to test the behavior of KBDI, modified for peatland wildfires in Central Kalimantan under tropical climate conditions affected by the El Niño disaster in 2015, when the El Niño conditions caused a significant rainfall decline in most parts of Indonesia.

## 2. KBDI Index Modification

### 2.1. KBDI and Wildfire Risk Assessment

KBDI was first introduced to manage forest fire control under a sub-tropical climate. This index represents the net effect of evapotranspiration and precipitation on cumulative moisture deficiency in deep duff or upper soil layers, and is related to the flammability of organic materials in the ground [43]. KBDI is applied to human activity-caused fire and sub-surface fire, and is determined using Eq. (1).

$$KBDI_t = KBDI_{t-1} + DF_t - RF_t, \quad \dots\dots \quad (1)$$

where $DF_t$ is drought factor (mm), $RF_t$ is rainfall factor (mm), $t$ is time (day).

The value of the rainfall factor ($RF_t$) is determined using meteorological data, in the form of annual rainfall and daily rainfall. An $RF_t$ of more than 5.1 mm/day is considered a reduction in the drought index and is determined using the following equation [43].

$$RF_t = \begin{cases} (R_t - 5.1), & \\ & R_t \geq 5.1 \text{ mm/day, 1st rainy day}, \\ R_t, & R_{t-1} \geq 5.1 \text{ mm/day}, \\ & \text{2nd and the next rainy day}, \\ 0, & R_t < 5.1 \text{ mm/day}, \end{cases} \quad (2)$$

where $R_t$ is daily rainfall at $t$ and $R_{t-1}$ is daily rainfall at $t-1$.

The drought factor ($DF_t$) was determined based on the basic theory of soil moisture degradation in the forest area by assuming the following: (1) the field capacity of the organic layer is considered as 203 mm of water in excess of moisture held by the layer at the wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall [43]. The basic formula of $DF_t$ from Eq. (18) of [43] is modified

**Table 1.** Climate variables and the coefficient drought factor.

| Variable | Subtropical | Tropical |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 1270 | 2540 |
| $a$ | 0.9667 | 0.4982 |
| $b$ | 0.0875 | 0.0875 |
| $c$ | 8.30 | 4.27 |
| $w_c$ | 203 | 203 |

with [37] for tropical condition, and [45] for the $a$, $b$, and $c$ coefficients as follows:

$$DF_t = (w_c - KBDI_{t-1}) \frac{\left(ae^{(bTm+1.5552)} - c\right) 10^{-3}}{1 + 10.88e^{(-0.001736R_0)}}, \quad (3)$$

where $DF_t$ is drought factor (mm), $w_c$ is corresponding field capacity of available water in the layer (mm), $KBDI_{t-1}$ is moisture deficiency (KBDI at $t-1$), $T_m$ is daily maximum air temperature (°C), $t$ is time increment (day), $R_0$ is average annual rainfall (mm), $a$ and $c$ are coefficients influenced by the mean annual rainfall ($R_0$), and $b$ is coefficient influenced by evapotranspiration.

In a sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm, maximum temperature ($T_m$) is 26.67°C, and corresponding field capacity of available water in the layer ($w_c$) is 203 mm [43]. $t_{26.67;R_0}$ from Eq. (13) of [43] gives $t_{26.67;R_0} = 56.41$ days. If $R = \infty$ and $R_0 = 1270$ mm for a subtropical climate, $t_{26.67,\infty}$ from Eq. (16) of [43] gives $t_{26.67,\infty} = 0.4545\, t_{26.67;1270} = 25.64$ days.

[37] modifies the drought-factor formula ($DF_t$) affected by tropical annual rainfall ($R_0$) as 2540 mm, $w_c$, and the temperature used is the same as that in [43], which is 26.67°C. $w_c$ is 203 mm. [37] adjusts the constants $t_{26.67,\infty}$ for a tropical condition from [37] as $t_{26.67,\infty} = 0.8831\, t_{26.67;2540} = 49.87$ days.

The coefficients $a$, $b$, and $c$ for the sub-tropical condition [43] and tropical condition [37] are listed in **Table 1**.

## 2.2. KBDI Index Modification for the Tropical Climate

### 2.2.1. KBDI Index Modification for Tropical Wetland

[37] modified $DF_t$ is affected by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients $a$ and $c$. It was concluded that the loss of evapotranspiration in the tropical climate is 15% higher relative to that in the sub-tropical climate; thus, the coefficient $b$ in **Table 2** become 0.0905 [37]. These coefficients are used as the modifications for the tropical wetland conditions in this paper.

### 2.2.2. KBDI Modified for Tropical Peatlands Followed by El Niño

The formula of $DF_t$ (Eq. (3)) has been developed to represent the average rainfall conditions for wildfire risk control in tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by the El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, as well a reduction in average rainfall [27]. In 2009, the Southern part of Kalimantan received low precipitation, which caused peatland drying and the easy spread of fires [46]. Analysis of rainfall from three stations in the study area indicates that when El Niño occurred in 2015, rainfall decreased by approximately 35% from the annual average rainfall. The annual rainfall in 2015 at the study area was 1650 mm. The evaporation time for the same temperature used by [43] was 26.67°C.

**Table 2.** Climate variables and the coefficient drought factor for tropical wetland and peatland condition.

| Parameter | Tropical wetland | Tropical peatland due to El Niño |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 2540 | 1650 |
| $a$ | 0.4982 | 0.3614 |
| $b$ | 0.0905 | 0.0905 |
| $c$ | 4.27 | 3.10 |
| $w_c$ | 203 | 400 |

In addition to the changes in the coefficients $a$ and $c$ on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 mm of the soil water available for evapotranspiration [43]. The $w_c$ value was on the scale from 0 to 203, where 0 denotes no moisture depletion, and 203 indicates the highest depletion [37]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on peatland research in the Netherlands that used a 400 mm depth for the reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire frequency and the reduction of groundwater level [47]. The Government Regulation of the Republic of Indonesia No. 57 of 2016 on peat ecosystem protection and management, clause 23 point 3, states that peat ecosystems with a cultivation function could be damaged if the water table depth is more than 400 mm below the peat surface [48]. Thus, for the El Niño modifications in this paper, $R_o$ is set as 1650 mm, $T_m$ is 26.67, and $w_c$ is 400. Based on the above concept, adjustment constants using Eqs. (13) and (16) of [43] in tropical peatland gives $t_{26.67;1650} = 111.17$ days and $t_{26.67,\infty} = 0.617\, t_{26.67;1650} = 68.6$ days.

The decrease in rainfall affects the values of the coefficients $a$ and $c$ on $DF_t$ in Eq. (3). The coefficient $b$ used is 0.0905 [37]. **Table 2** shown climate variables for modification 1 (tropical wetland conditions [37]) and modification 2 (tropical peatland conditions due to El Niño) in 2015.

In the previous study, four fire danger classes were used, from 0 to 203 mm [37]. In the present study, the

**Table 3.** Drought index classes of KBDI modified for tropical peatland conditions.

| Classes | KBDI index | KBDI index in tropical peatland |
|---|---|---|
| low | 0–100 | 0–200 |
| moderate | 101–150 | 201–300 |
| high | 151–175 | 301–350 |
| extreme | > 175 | > 350 |

new value of $w_c$ causes a change in the KBDI classes. The water table ranges from 0 to 400 mm. The water table at 400 mm below the surface is considered to cause the maximum drought index and a potential fire risk in the peat ecosystem. A water table of 0 mm, where water is on the surface of the land, is expressed as an ideal peat condition that is always inundated. Based on the new $w_c$ value for the peatland condition, the value of the KBDI classes is corrected. Drought index classes are classified into four levels, as presented in **Table 3**.

## 3. Study Area and Methods

### 3.1. Study Area

The Mega Rice Project consists of one million hectares of peatland in Central Kalimantan and caused damage to the tropical peat forest [49]. It caused the large wildfire in 2015. The highest number of fire alerts (NFA) was recorded on October 19, 2015. The conditions of peatland wildfires in Kalimantan captured by the Moderate Resolution Imaging SpectroRadiometer (MODIS) from the NASA Aqua satellite are illustrated in **Fig. 1**. This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke signals the conditions [50].

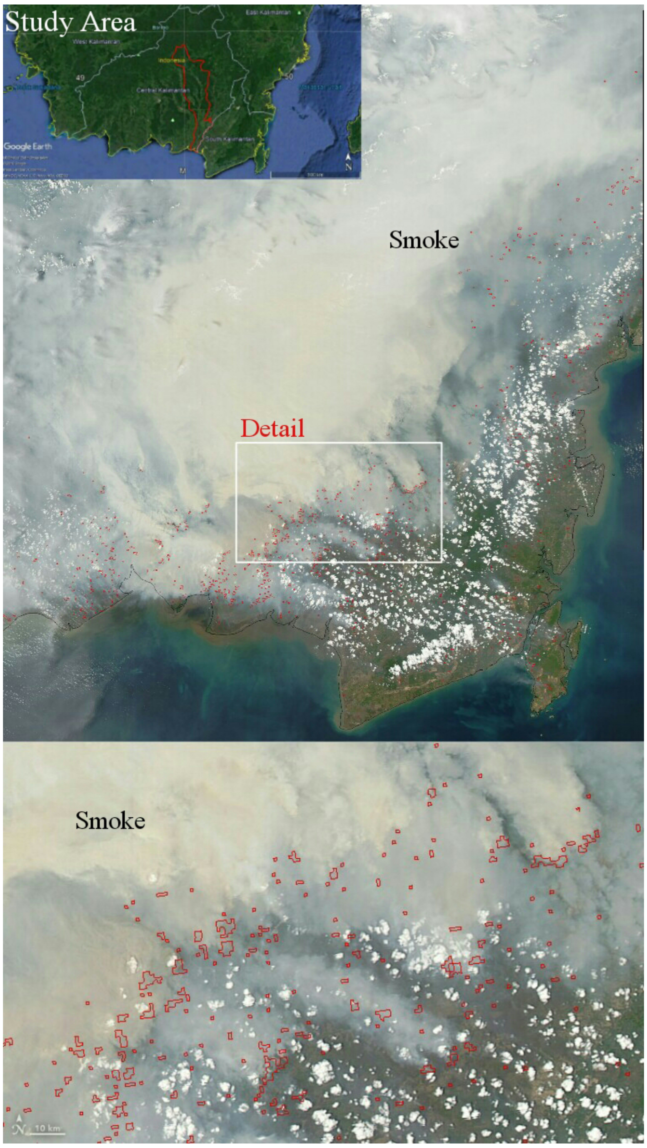



**Fig. 1.** Wildfires hazard was found on October 19, 2015.

The present study was conducted in Block A, the Ex-Mega Rice Project (EMRP) located in Mantangai sub-District, Kapuas District, Central Kalimantan Province, which is illustrated in **Fig. 2(a)** [51]. **Fig. 2(b)** depicts some post-wildfire conditions in the peatland around Block A in November 2015. This area underwent land clearing, which caused the peatland to become dry and flammable. A drought index for peat wildfire risk assessment was evaluated under peat wildfire conditions in 2015.

The largest wildfires occur in tropical peatlands, including the tropical peatland in Indonesia. Peat wildfires have previously occurred in the EMRP area in Central Kalimantan [52]. The Mega Rice Project was started legally on a Presidential decree 82/1995. The project caused 400 thousand ha of tropical rainforest cutting. EMRP was a program that failed considerably to conserve the peatlands in Indonesia [49]. The exploitation of forest and peatland in EMRP land occurred due to the construction of drainage network systems [49]. The drainage network systems divide peat domes, causing massive damage and resulting in the loss of function as field reservoirs, land subsidence, and a decreased water table [53]. This phenomenon causes irreversible peat drying, which triggers forest and peatland wildfires [54]. In addition to the decreased water table, peatland wildfires are caused by the rainfall reduction (the number of dry days), known as the El Niño phenomenon, which usually occurs from September to October.

Rainfall data was recorded near the study area, such as in Tjilik Riwut, Beringin, and Sanggu Rain Station [55]. Rainfall data was analyzed from 01 January 2015 to 31 December 2015, and there were a total of 263 dry days, which is more than 70% of the total in 2015. The NFA in the form of hotspots were obtained by using NASA's Active Fire Data to determine the possible location of fires. The system uses NASA MODIS satellites, which survey the entire earth every 1–2 days. The sensors on these satellites detect hot marks in infrared spectral waves. Dur-

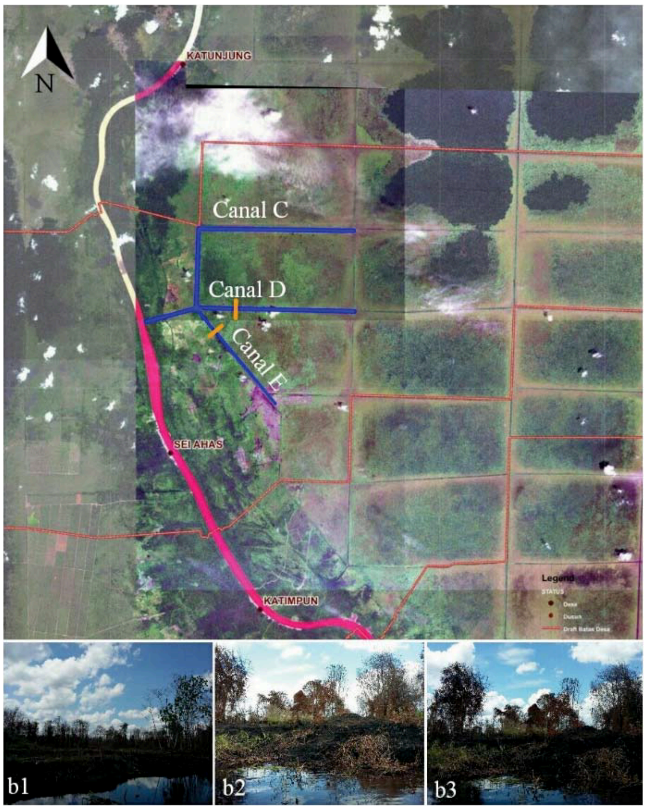



**Fig. 2.** (a) Study area on Block A of Ex-Mega Rice Project and (b) post-wildfire conditions in peatlands around canal C (b1), Canal D post-wildfire (b2), and Canal E post-wildfire (b3) in November 2015.

ing the processing of the satellite imagery, the algorithm looks for a heat sign and detects it as a fire sign. The system can indicate where a fire occurred and can provide a warning of high risk areas [56].

## 3.2. Methods

In this study, a modified KBDI was developed for wildfire risk assessment under tropical peatland conditions influenced by El Niño, with modification to the baseline groundwater conditions for peatland affecting the $w_c$ value. The modified index was compared with KBDI under tropical wetland conditions [37]. The results of the two index modifications were compared against NFA recorded in the peat forest, Block A, Mantangai Subdistrict, Central Kalimantan Province, in 2015.

# 4. Results and Discussion

## 4.1. Rainfall Data

Based on the observations, rainfall from the three rain stations was almost uniform, with an average annual rainfall of 1650 mm in 2015. This rainfall value was below the average annual rainfall of areas with a tropical climate. The mean annual rainfall for areas with a tropical climate ranged from 2000 to 3000 mm [37]. This decrease in rainfall was caused by the El Niño in Indonesia. The average monthly rainfall at the three stations in the study site was the highest (134 mm) in November 2015. The net rainfall or rainfall factor ($RF_t$) was calculated using Eq. (2) to determine the number of dry days (**Table 4**). Dry day conditions were found on 29 days in July, 28 days in August, 30 days in September and 27 days in October 2015.

**Table 4.** Number of dry day and fire alerts.

| | Number of the dry day | Number of fire alerts |
|---|---|---|
| Jan | 9 | 1 |
| Feb | 26 | 0 |
| Mar | 17 | 0 |
| Apr | 17 | 3 |
| May | 23 | 1 |
| Jun | 21 | 1 |
| Jul | 29 | 19 |
| Aug | 28 | 488 |
| Sep | 30 | 1272 |
| Oct | 27 | 1746 |
| Nov | 18 | 10 |
| Dec | 16 | 3 |

## 4.2. Number of Fire Alerts Data

In 2015, there were 30,121 NFA events in the Central Kalimantan Province and 3,544 events in the Mantangai Sub-district. There were 3525 NFA events in Mantangai from July to November 2015, as much as 12.1% from the 29,171 events in Central Kalimantan. NFA increased from July to November 2015, and the largest number of NFA was observed in October 2015, with 1,741 events. This data indicates that the number of fire alerts in October represents half of the NFA for the year 2015, as presented in **Table 4**.

## 4.3. Keetch-Byram Drought Index (KBDI) Analysis

The results of the analysis using $DF_t$, under tropical wetland conditions [37] and under tropical peatland conditions influenced by the El Niño phenomenon are depicted in **Fig. 3**.

**Figure 3** depicts an added line for the beginning of the extreme index, at 175 mm for KBDI modified for the tropical wetland condition, and at 350 mm for KBDI modified for tropical peatland conditions. The KBDI level, with $DF_t$ formula for tropical wetland conditions, for a low index level from 0–100 was 218 values, the moderate index from 101–150 was 42 values, the high drought index from 151–175 was as much as 56 values, and the extreme drought index of more than 175 was 49 values. In the calculation of KBDI, with the modified $DF_t$ formula for tropical peatland conditions including El Niño phenomenon, there were 59 values from the high level,

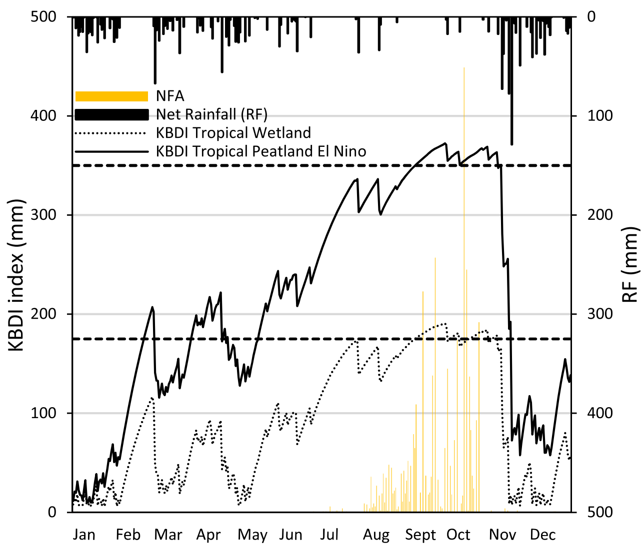



**Fig. 3.** Comparison of KBDI for tropical wetland and the modified KBDI for tropical peatland with the El Niño phenomenon.

**Table 5.** Drought level conditions.

| | Wetland conditions | | | | Peatland conditions due to El Niño | | | |
|---|---|---|---|---|---|---|---|---|
| | Low | Mod | High | Extreme | Low | Mod | High | Extreme |
| Jan | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |
| Feb | 23 | 5 | 0 | 0 | 26 | 2 | 0 | 0 |
| Mar | 30 | 1 | 0 | 0 | 30 | 1 | 0 | 0 |
| Apr | 30 | 0 | 0 | 0 | 21 | 9 | 0 | 0 |
| May | 28 | 3 | 0 | 0 | 20 | 11 | 0 | 0 |
| Jun | 25 | 5 | 0 | 0 | 0 | 30 | 0 | 0 |
| Jul | 0 | 16 | 15 | 0 | 0 | 12 | 19 | 0 |
| Aug | 0 | 12 | 19 | 0 | 0 | 1 | 30 | 0 |
| Sep | 0 | 0 | 7 | 23 | 0 | 0 | 8 | 22 |
| Oct | 0 | 0 | 9 | 22 | 0 | 0 | 0 | 31 |
| Nov | 20 | 0 | 6 | 4 | 15 | 5 | 2 | 8 |
| Dec | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |

and the extreme drought conditions increased to 61 occurrences, from July until November 2015. The class index is presented in **Table 5**.

Owing to the 35% reduction in rainfall occurring in the study area in 2015 due to El Niño, and the change in $w_c$ caused by groundwater table change, the extreme drought index increased. High and extreme class results started at the beginning of the dry season from July. In calculating KBDI, with $DF_t$ formula under tropical wetland conditions and tropical peatland conditions, high drought levels began to occur in early July 2015. Extreme drought levels began to occur in September 2015.**Fig. 4** shows the high and extreme classes in KBDI response (with the formula for tropical wetland conditions shown as modification 1, and KBDI with $DF_t$ under tropical peatland conditions including El Niño as modification 2) against fire risk assessment represented by the number of fire alerts.

**Figure 4** shows the high and extreme drought index results from the beginning of July to November 2015, representing the occurrence of fires beginning in July 2015, from KBDI modification for tropical wetland conditions and tropical peatland conditions. Two important findings are:

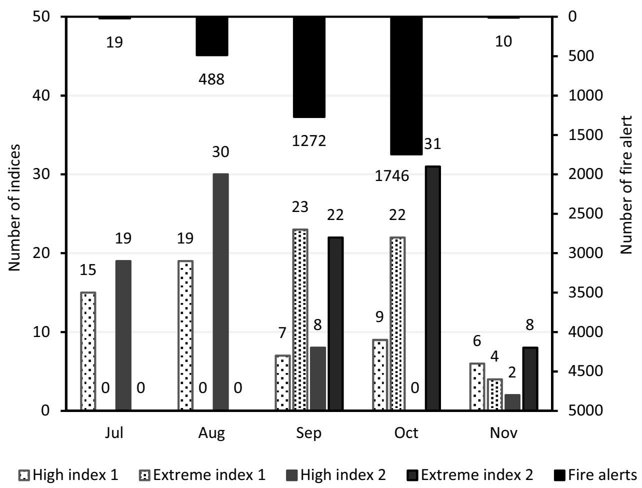



**Fig. 4.** Correlation between Keetch-Byram drought index (KBDI) values and number of fire alerts (NFA).

1. Index response with the $DF_t$ formula for tropical wetland conditions

   Based on the analysis of KBDI with the $DF_t$ formula for tropical wetland conditions, no extreme drought occurred at the beginning of July and August. Extreme drought indices occurred in September 2015 in 23 events, October 2015 in 22 events, and November 2015 in four events. Based on NFA data recorded in July, the study site had 19 fire alerts, followed by 488 fire alerts in August, 1272 fire alerts in September, and 1746 fire alerts in October. The highest level of extreme index results occurred in September 2015.

2. KBDI response to a corrected $DF_t$ for tropical peatland conditions

   In the corrected $DF_t$ formula for tropical peatland conditions affected by El Niño, with a rainfall reduction of 35% with $R_0 = 1650$ mm and groundwater level 400 mm, high to extreme drought levels were observed from September to November 2015, with 61 indices. The results for the extreme drought index were 22 events in September, 31 events in October, and eight events in November 2015. This finding is consistent with the NFA data, where the starting point of fire is in July and the highest number of fire alerts are in October, with 1746 fire alerts. These fire alerts conditions in October 2015 are predicted by extreme drought conditions that cover the whole 31 days of the month.

### 4.4. Discussion

This study was conducted on a peat fire situation in 2015 in Central Kalimantan. This study conducted analysis on KBDI results for data collected in 2015, comparing corrected $DF_t$ modifications for tropical wetland conditions and tropical peatland conditions and the number of fire alerts in Mantangai Sub-district, with the results demonstrating that:

1. The modifications of the KBDI index for tropical peatland conditions adequately represents the real fire risk assessment data recorded in 2015. KBDI modification for tropical peatland conditions increases from the high index level to the extreme index level to the value of 350 and continues to rise to the maximum value of 400 starting on September 9, 2015, representing 109 NFA events that day. KBDI modification for tropical wetland conditions increased from the high index level to the extreme index level on September 9, 2015, represented by 65 fire alerts. These modifications of the KBDI for the conditions of tropical peatlands can demonstrate the potential for fire disasters in the study area.
2. In October 2015, there were 1746 NFA events in Mantangai, with the KBDI modification for tropical peatland conditions resulting in 31 days of extreme indices, while the KBDI wetland modification only resulted in 22 days with extreme indices. According to the modified $DF_t$ for tropical peatland conditions, the extreme class is 12 points higher than KBDI modified for tropical wetland conditions. It rises from September to November 2015 in the study area, with the corrected water table of 400 mm.
3. The highest number of NFA was on October 14, 2015, with 449 fire alerts events represented by the extreme value in KBDI modified for tropical peatland conditions, while the KBDI modified for wetland conditions only resulted in high index results, as shown in **Fig. 3**.
4. The statistical parameter for extreme classes compared against the number of fires from July to November using linear regression for modification 1 gave $R^2$ as 0.828 with $p$-value 0.03. Modification 2 for tropical peatlands gave $R^2$ as 0.829 with $p$-value 0.03. It has been shown that both modifications give a good statistical result.

The modified KBDI for tropical peatland conditions seems to perform better in wildfire risk assessment in the Central Kalimantan during El Niño in 2015 compared with other KBDI formulas. The results follow those of previous Kalimantan Forests and Climate Partnership (KFCP) observations. A study by KFCP from 2004 to 2013 in the same study area showed daily wildfire patterns indicating fires at the same locations and in the same months. Fires occurred from late July to early November. The peak of the fires occurred in September [51]. Previous research from 2001 to 2010 found large-scale land management practices using fire, which caused smoke hazards from mid-August to late October [52]. We can consider the use of the empirical drought index formula for tropical peatland conditions to have several general principles, which are as follows:

1. The KBDI formula must be based on the net rainfall factor set by the $R$ threshold. This threshold for tropical conditions still uses the same threshold as in the previous KBDI formula defined under sub-tropical conditions.
2. Peatland wildfires are not just caused by meteorological conditions but also by many internal factors in the soil, such as peat decomposition, physical properties, water holding capacity [52], and capillarity rise.
3. Peatland wildfires are also affected by unwise peatland management, such as building drainage canals in the peat dome, which results in a change in the water table.

Evaluation of the performance of KBDI under a range of climatic conditions, including a sub-tropical climate, Mediterranean climate, and tropical climate, reports that KBDI is a flexible drought index for almost all climatic conditions and may represent an important tool for forest fire control.

## 5. Conclusion

KBDI modification, by correcting the $DF_t$ formula for the referenced water table level for peatland and with the influence of rainfall reduction due to the El Niño phenomenon, can accurately represent NFA in peatland. The analysis shows the results of the KBDI; drought factor ($DF_t$) correction for tropical peatland conditions, gave an extreme index (375 to 400 mm) occurring from September 9, 2015. Twenty-seven dry days caused 31 days of extreme index, represented by 1746 fire alerts in October 2015. The highest NFA number was on October 14, 2015 with 449 fire alerts events represented with this formula as an extreme value. Therefore, this formula provided satisfactory results in the El Niño conditions of 2015. Further testing is still needed to prove the formula for other El Niño events. In addition to the meteorological and water table factors in the KBDI formula, which affect drought management in peatland, several supporting factors must be considered, such as peat decomposition, physical characteristics, water holding capacity, and capillarity rise. The degraded physical properties of peatlands also lead to larger wildfires with the same number of dry days.

**Acknowledgements**

This study was completed with partial funding from Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) from the DRPM Ditjen Penguatan Riset dan Pengembangan, Ministry of Research, Technology, and High Education – the Republic of Indonesia through LPPM Universitas Gadjah Mada.

**References:**

[1] C. E. Stockwell et al., "Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia, during the 2015 El Niño," Atmos. Chem. Phys., Vol.16, No.18, pp. 11711-11732, 2016.

[2] S. E. Page, F. Siegert, J. O. Rieley, H.-D. V. Boehm, A. Jaya, and S. Limin, "The amount of carbon released from peat and forest fires

in Indonesia during 1997," Nature, Vol.420, No.6911, pp. 61-65, 2002.

[3] W. C. Adinugroho, I. N. N. Suryadiputra, B. H. Saharjo, and L. Siboro, "Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut," Wetlands International: Indonesia Programme, 2004.

[4] H. Hayasaka, "Recent Large-Scale Fires in Boreal and Tropical Forests," J. Disaster Res., Vol.2, No.4, pp. 265-275, DOI: 10.20965/jdr.2007.p0265, 2007.

[5] Wahyunto, S. Ritung, Suparto, and H. Subagjo, "Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan," Wetlands International: Indonesia Programme, 2005.

[6] S. Ritung et al., "Peta Lahan Gambut Indonesia Skala 1:250.000," 2011.

[7] H. Vasander, "3. Overview of types of peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 15-18, 2014.

[8] S. W. Atmojo, "Pengelolaan Lahan Gambut," UNS Press, 2014.

[9] S. Najiyati, L. Muslihat, I. Nyoman, and N. Suryadiputra, "Panduan Pengelolaan Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[10] I. T. C. Wibisono, L. Siboro, and I. N. N. Suryadiputra, "Panduan Rehabilitasi dan Teknik Silvikultur di Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[11] J. P. Andriesse, "Nature and Management of Tropical Peat Soils," FAO Soils Bulletin 59, Food and Agriculture Organization of the United Nations (FAO), 1988.

[12] N. Yulianti and H. Hayasaka, "Recent Active Fires under El Niño Conditions in Kalimantan, Indonesia," American J. of Plant Sciences, Vol.4, No.3A, pp. 685-696, 2013.

[13] S. Page and A. Hooijer, "6. Environmental impacts and consequences of utilizing peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 27-35, 2014.

[14] P. Sofan, Y. Vetrita, F. Yulianto, and M. R. Khomarudin, "Multitemporal remote sensing data and spectral indices analysis for detection tropical rainforest degradation: case study in Kapuas Hulu and Sintang districts, West Kalimantan, Indonesia," Nat. Hazards, Vol.80, No.2, pp. 1279-1301, 2016.

[15] K. Becek and A. B. Horwath, "Is vegetation collapse on Borneo already in progress?," Nat. Hazards, Vol.85, No.2, pp. 1279-1290, 2017.

[16] H. Herawati and H. Santoso, "Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia," For. Policy Econ., Vol.13, No.4, pp. 227-233, 2011.

[17] A. C. Watts and L. N. Kobziar, "Smoldering Combustion in Organic Soils: Peat and Muck Fires in the Southeastern U.S.," South. Fire Exch., 2012.

[18] A. Sandhyavitri, R. Amri, and D. Fermana, "Development of Underground Peat Fire Detection," Int. Conf. on Technology, Innovation, and Society (ICTIS2019), pp. 439-444, 2016.

[19] X. Huang, F. Restuccia, M. Gramola, and G. Rein, "Experimental study of the formation and collapse of an overhang in the lateral spread of smouldering peat fires," Combust. Flame, Vol.168, pp. 393-402, 2016.

[20] G. Rein, N. Cleaver, C. Ashton, P. Pironi, and J. L. Torero, "The severity of smouldering peat fires and damage to the forest soil," Catena, Vol.74, No.3, pp. 304-309, 2008.

[21] M. G. L. Van Nieuwstadt and D. Sheil, "Drought, fire and tree survival in a Borneo rain forest, East Kalimantan," Indonesia J. of Ecology, Vol.93, No.1, pp. 191-201, 2005.

[22] S. Martín, M. Rodríguez, J. M. Moreno, and D. G. Angeler, "Complex ecological responses to drought and fire-retardant contamination impacts in ephemeral waters," Water. Air. Soil Pollut., Vol.225, No.8, DOI: 10.1007/s11270-014-2078-7, 2014.

[23] M. Solh and M. van Ginkel, "Drought preparedness and drought mitigation in the developing world's drylands," Weather Clim. Extrem., Vol.3, pp. 62-66, 2014.

[24] R. S. Pulwarty and M. V. K. Sivakumar, "Information systems in a changing climate: Early warnings and drought risk management," Weather Clim. Extrem., Vol.3, pp. 14-21, 2014.

[25] M. L. Khandekar, T. S. Murty, D. Scott, and W. Baird, "The 1997 El Niño, Indonesian Forest fires and the Malaysian Smoke problem: A deadly combination of natural and man-made hazard," Nat. Hazards, Vol.21, No.2-3, pp. 131-144, 2000.

[26] R. D. Field, Y. Wang, O. Roswintiarti, and Guswanto, "A drought-based predictor of recent haze events in western Indonesia," Atmos. Environ., Vol.38, No.13, pp. 1869-1878, 2004.

[27] M. Pidwirny, "El Niño, La Niña and the Southern Oscillation," 2006, http://www.physicalgeography.net/fundamentals/7z.html [accessed March 7, 2016]

[28] N. Wanders, H. A. J. van Lanen, and A. F. van Loon, "Indicators for drought characterization on a global scale," WATCH Technical Report No.24, p. 93, 2010.

[29] A. Hasegawa, M. Gusyev, and Y. Iwami, "Meteorological drought and flood assessment using the comparative SPI approach in Asia under climate change," J. Disaster Res., Vol.11, No.6, pp. 1082-1090, DOI: 10.20965/jdr.2016.p1082, 2016.

[30] D. A. Wilhite and M. D. Svoboda, "Drought early warning systems in the context of drought preparedness and mitigation," Early Warn. Syst. drought Prep. drought Manag., pp. 1-21, 2000.

[31] M. A. Gusyev, A. Hasegawa, J. Magome, D. Kuribayashia, H. Sawanoa, and S. Lee, "Drought assessment in the Pampanga River basin, the Philippines – Part 1: Characterizing a role of dams in historical droughts with standardized indices," 21st Int. Congress on Modeling and Simulation, pp. 1586-1592, 2015.

[32] R. A. Adesiji, P. A. Adeoye, and A. O. Gbadebo, "Review Article Effects of Water Table Fluctuations on Peatland-A Review," Sch. J. Eng. Technol., Vol.2, No.3C, pp. 482-487, 2014.

[33] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Pengaruh Karakteristik Gambut Terdegradasi terhadap Kebakaran Lahan Gambut," Prosiding Seminar Nasional Lingkungan Lahan Basah, Vol.3, pp. 347-351, 2018.

[34] R. R. Heim, "A review of twentieth-century drought indices used in the United States," Bulletin of the American Meteorological Society, 2002.

[35] H.-R. Byun and D. A. Wilhite, "Objective Quantification of Drought Severity and Duration," J. of Climate, Vol.12, No.9, pp. 2747-2756, 1999.

[36] World Meteorological Organization (WMO) and Global Water Partnership (GWP), "Handbook of drought indicators and indices," Integrated Drought Management Programme (IDMP), No.1173, 2017.

[37] M. Taufik, B. I. Setiawan, and H. a. J. van Lanen, "Modification of a fire drought index for tropical wetland ecosystems by including water table depth," Agric. For. Meteorol., Vol.203, pp. 1-10, 2015.

[38] D. X. Viegas, G. Bovio, A. Ferreira, A. Nosenzo, and B. Sol, "Comparative study of various methods of fire danger evaluation in southern Europe," Int. J. Wildl. Fire, Vol.9, No.4, p. 235, 1999.

[39] P. Groisman et al., "Changes in Precipitation Distribution Spectra and Contemporary Warming of the Extratropics: Implications for Intense Rainfall, Droughts, and Potential Forest Fire Danger," 16th Conf. on Climate Variability and Change, Session No.12.5, 2005.

[40] C. Willis et al., "The Development of a National Fire Danger Rating System for South Africa," CSIR Water, Environment and Forestry Technology, 2001.

[41] J. Skvarenina, J. Mindas, J. Holecy, and J. Tucek, "Analysis of the natural and meteorological conditions during two largest forest fire events in the Slovak Paradise National Park," J. Meteorol., Vol.7, pp. 167-171, 2003.

[42] A. J. Dowdy, G. a Mills, K. Finkele, and W. De Groot, "Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index," CAWCR Technical Report No.10, 2009.

[43] J. J. Keetch and G. M. Byram, "A Drought Index for Forest Fire Control," U.S. Department of Agriculture, 1968.

[44] G. Petros, M. Antonis, and T. Marianthi, "Development of an adapted empirical drought index to the Mediterranean conditions for use in forestry," Agric. For. Meteorol., Vol.151, No.2, pp. 241-250, 2011.

[45] A. Garcia-Prats, D. C. Antonio, F. J. G. Tarcísio, and M. J. Antonio, "Development of a Keetch and Byram – Based drought index sensitive to forest management in Mediterranean conditions," Agric. For. Meteorol., Vol.205, pp. 40-50, 2015.

[46] K. Kaku and A. Held, "Sentinel Asia: A space-based disaster management support system in the Asia-Pacific region," Int. J. Disaster Risk Reduct., Vol.6, pp. 1-17, 2013.

[47] E. I. Putra, H. Takahashi, H. Hayasaka, and A. Usup, "Recent Peat Fire Activity in the Mega Rice Project Area, Central Kalimantan, Indonesia," J. Disaster Res., Vol.3, No.5, pp. 334-341, DOI: 10.20965/jdr.2008.p0334, 2008.

[48] "Peraturan Pemerintah (PP) No.57: Peraturan Pemerintah (PP) tentang Perubahan atas Peraturan Pemerintah Nomor 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut," 2016.

[49] T. Notohadiprawiro, "Mega-Project of Central Kalimantan Wetland Development for Food Crop Production, Belief and Truth," Proc. of the Int. Peat Symposium: The Spirit of Peatlands, 1998.

[50] NASA, "Earth Observatory," Earth Observatory, 2015, https://earthobservatory.nasa.gov/images/86847/heavy-smoke-blankets-borneo [accessed January 24, 2016]

[51] KFCP, "Peta Rencana Pola Tata Guna Lahan Desa Sei Ahas," Indonesia: Indonesia-Australia Forest Carbon Partnership (IAFCP), 2014.

[52] H. Hayasaka, I. Noguchi, E. Indra, N. Yulianti, and K. Vadrevu, "Peat-fire-related air pollution in Central Kalimantan, Indonesia," Environ. Pollut., Vol.195, pp. 257-266, 2014.

[53] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Restoration of peat dome in ex-Mega rice project area in Central Kalimantan," AIP Conf. Proc., Vol.1977, 2018.

[54] I. N. N. Suryadiputra et al., "2005 Buku_Suryadiputra_Panduan Penyekatan Parit (Indonesia)," Wetlands International: Indonesia Programme, 2005.

[55] BMKG, "Data Hujan Online," 2019, http://dataonline.bmkg.go.id [accessed January 30, 2016]

[56] D. C. Morton, R. S. Defries, J. T. Randerson, L. Giglio, W. Schroeder, and G. R. van der Werf, "Agricultural intensification increases deforestation fire activity in Amazonia," Glob. Chang. Biol., Vol.14, No.10, pp. 2262-2275, 2008.

**Name:**
Novitasari Novitasari

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
2005- Lecturer, Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat
2015- Student, Civil Engineering Doctoral Program, Universitas Gadjah Mada

**Selected Publications:**
• "Restoration of Peat Dome in Ex-Mega Rice Project Area in Central Kalimantan," American Institute of Physics Conf. Proc., 1977, 040008 (2018), DOI: https://doi.org/10.1063/1.5042978, 2018.

**Academic Societies & Scientific Organizations:**
• Indonesian Association of Hydraulic Engineers (HATHI)
• Indonesia Water Resources Association (JSDA-Indonesia)

**Name:**
Joko Sujono

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
1989- Lecturer, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "A comparison of techniques for hydrograph recession analysis," Hydrological Processes, Vol.18, No.3, pp. 403-413, 2004.
• "Improving the water productivity of paddy rice (Oryza sativa L.) cultivation through water saving irrigation treatments," Agricultural Sciences, Vol.2, No.4, pp. 511-517, 2011.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Sciences (IAHS)
• Indonesian Association of Hydraulic Engineers (HATHI)

**Name:**
Sri Harto

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
1994-1997 Dean, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "The characteristics of Unit Hydrographs with different scale of antecedent Soil Moisture Condition," J. of Engineering and Applied Sciences, Vol.11, Issue 12, pp. 2594-2601, 2016.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Science (IAHS)
• International Association of Hydro-Environment Engineering and Research (IAHR)
• Indonesian Association of Hydraulic Engineers (HATHI)

**Name:**
Azwar Maas

**Affiliation:**
Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada

**Address:**
Jl. Flora, Bulak Sumur, Yogyakarta 55281, Indonesia

**Brief Career:**
2012-2016 Head of Soil Science Study Program, Faculty of Agriculture, Universitas Gadjah Mada
2016- Chairman of Expert for Peatland Restoration Agency (BRG)

**Selected Publications:**
- "The tolerance of photosynthesis of some maize cultivars (Zea mays L.) to waterlogging at different stages of growth," Int. J. on Advanced Science, Engineering and Information Technology, Vol.7, Issue 4, pp. 1296-1301, 2017.
- "Characteristics of three biochar types with different pyrolysis time as ameliorant of peat soil," Indian J. of Agricultural Research. Vol.51, Issue 5, pp. 458-462, 2017.

**Academic Societies & Scientific Organizations:**
- Soil Science Sociaty (HIT)
- Indonesian Wild and Land Fires Associate (Karhutra)
- Indonesia Disaster Expert (IABI)

**Name:**
Rachmad Jayadi

**Affiliation:**
Associate Professor, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
2009-2012 Head of Master Program in Natural Disaster Management, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head of Undergraduate Program in Civil Engineering, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
- "Impact of Sedimentation Counter Measure on the Performance of Flood Control: A Case Study of Wonogiri Reservoir," Int. J. of Applied Mechanics and Materials, Vol.881, pp. 78-85, DOI: 10.4028/www.scientific.net/AMM.881.78, 2018.
- "Improving Spatial Rainfall Estimates at Mt. Merapi Area Using Radar-Rain Gauge Conditional Merging," J. Disaster Res., Vol.14 No.1, pp. 69-79, DOI: 10.20965/jdr.2019.p0069, 2019.

**Academic Societies & Scientific Organizations:**
- Indonesian Association of Hydraulic Engineers (HATHI)
- Indonesian National Committee of ICID (INACID)

Paper: Dr14-7-9565;

# Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia During El Niño Phenomenon

**Novitasari Novitasari***, **Joko Sujono***,†, **Sri Harto***, **Azwar Maas****, **and Rachmad Jayadi***

*Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Jl. Grafika No 2, Yogyakarta 55281, Indonesia
†Corresponding author, E-mail: jsujono@ugm.ac.id
**Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia
[Received August 1, 2018; accepted September 4, 2019]

**Peatland wildfires, especially in tropical ecosystems, are often caused by drought, and lead to smoke and other related problems in all aspects of community life in Indonesia, especially in Central Kalimantan. Drought is worsened by the number of dry days in the dry season, known as the El Niño phenomenon, and the drainage system in a peatland. Additionally, drought decreases the water table and increases the probability of occurrence of wildfires in peatland areas. This study aims to modify the numerical formula of the drought factor ($DF_t$) in the Keetch–Byram drought index (KBDI) based on tropical peatland wildfire conditions in Central Kalimantan during the El Niño phenomenon in 2015. Furthermore, it applies a revised peatland water table reference of 400 mm below the ground surface, based on previous research and the Government regulation on peatland ecosystem protection and management in Indonesia. These El Niño conditions caused a rain decline of approximately 35% in Block A, Ex-Mega Rice Project, Mantangai sub-District, Kapuas District, Central Kalimantan Province. The modified KBDI is compared with the Number of Fire Alerts (NFA) using NASA's Active Fire Data in 2015. The analysis results demonstrate that the modified $DF_t$ under tropical peatland conditions leads to an increase in the drought index value, beginning on the driest days between July and November 2015. The value of the KBDI drought index increases from the high to the extreme index from September to November 2015, when as many as 61 extreme drought indices became indicators for peatland wildfire risk assessment. The extreme KBDI is directly proportional to the NFA recorded during 2015, and the highest number of fire alerts is observed for October 2015, with 1746 fire alerts within 31 days and extreme drought indices from 27 days. Hence, this modified formula is suitable for wildfire conditions on this peatland in Central Kalimantan. Overall, the modified $DF_t$ can be successfully applied to the El Niño phenomenon in 2015.**

**Keywords:** Keetch–Byram drought index (KBDI), number of fire alerts, El Niño, water table, peatland wildfire

## 1. Introduction

The forest wildfires of 2015 were the largest wildfires in Indonesia for the last ten years in terms of the amounts of trace gases and aerosols released, which have been monitored in several previous studies [1]. The severity of theses wildfires was similar to the disaster that occurred in 1997 [2]. Forest wildfires in Indonesia not only occur in upland environments but also in wetlands [3]. These forest wildfires mainly occur in tropical peatlands [4]. Wildfires in tropical peatlands occupy an area equivalent to 10.8% of Indonesia's land area [5]. Among tropical countries, Indonesia has the largest area of tropical peatland, which is approximately 14 million ha and is mainly found in Sumatra, Kalimantan, and Papua [6]. Indonesia's peatland is a part of the wider tropical peatland habitat in Southeast Asia [7]. Tropical peat comprises accumulated organic materials in a wetland ecosystem [8]. Tropical peat is formed in forests under wetland conditions with the production of large quantities of organic materials [9, 10].

Indonesia's peatland has been developed by the building drainage systems. Canals are intended to decrease the water table in the peatland. These canals are utilized to support the cultivation of crops, such as oil palm and acacia. The resulting decrease in the water table can cause the peat to become overdrained and thereby make it flammable, damaging the ecological balance and eliminating forest and peatland biodiversity [10]. Peatland is commonly burned to minimize production cost; however, this practice may cause uncontrolled peatland wildfires [11]. In addition to human-caused fires, peatland wildfires are caused by meteorological drought factors, such as a lack of rainfall and high evaporation rate [12]. Dry peatland, which is fundamentally unstable, loses water from the soil, allowing oxygen to penetrate the pores and oxidize the peat through biological and chemical processes [13]. Peatland wildfires not only cause rainforest degradation [14] and affect biodiversity [15], but also release smoke and carbon emissions to the atmosphere; fire harms nearby communities and leads to the loss of lives and property [16]. Peatland wildfires slowly spread through the surface, and those classified as smoldering fires are absorbed by the subsurface and organic lay-

ers [17]. This type of fire is difficult to detect [18]. Smoldering wildfire causes the lateral spread of flames under different moisture and wind conditions [19] and creates strong smoke that spreads over extensive areas [20]. Drought and fires are important components for the assessment of the dynamics of tropical peat forests [21].

The risk of wildfires increases as the frequency and duration of drought increases [22]. Natural drought is a condition that cannot be managed [23] and has affected millions of square kilometers of land in many areas, such as North America, West Africa, and East Asia [24]. In Indonesia, drought in peatlands leads to sub-surface wildfires all around the ecosystem. These wildfires cause smoke to spread to other countries, such as Malaysia [25]. Fires occur almost every year in Indonesia during the dry season. Wildfires usually occur between June and September and intensify during El Niño [26]. El Niño is a natural phenomenon characterized by the warming of temperatures in the Pacific Ocean and causes drought in the Asian region [27]. El Niño decreases the amount of rainfall in Indonesia [16].

A situation with lower than average water availability due to climate variability may cause drought [28]. The limitations for drought have not yet been widely agreed upon, which indicates that drought is a region specific event. However, there are several types of drought that can be used as reference. A decreased amount of rainfall is also one of the causes of drought, namely, meteorological drought [29]. This type of drought appears in various components of the hydrological cycle [30]. Drought is not only caused by meteorological factors (lack of precipitation), but also by agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows), and socio-economic (lack of water supply to meet water demand) factors [29, 31].

In Indonesia, meteorological drought is often accompanied by dry peatland caused by the decline in the water table and changes in the physical properties of peat due to the drainage system. Some fires are also caused by human activities, such as land clearing. The blocking of canals can reduce the degradation of peatlands to a larger extent [32]. Additionally, it can also help to maintain the water table [33] to prevent drought on peatlands.

The process by which drought leads to wildfires is a complex process, and a drought index cannot be easily specified. No index can fully explain the complexity of drought and its impacts [34]. A drought index can be used as an indicator to determine the classification of the drought level of a particular region or area [28]. Many drought indices have been expanded to appraise the scale, type, and impact of drought [35]. Many drought indices are easy to build and use, based on meteorology data, soil moisture, hydrology, and remote sensing [36]. One formula that uses meteorological data is the standardized precipitation index (SPI) [29] and the Keetch–Byram drought index (KBDI) [37].

Some drought indices are built for specific uses and environments. In forestry, many drought indices are designed for fire risk assessment [38]. The most widely used drought indices are the Nesterov index, Zhdanko index [39], Angstrom index [40], Baumgartner index [41], McArthur forest fire danger index [42], and KBDI [43]. KBDI is one of the most widely used indices for forest fire management under various climatic conditions [2, 34]. KBDI was first developed for forest fire management in the sub-tropical Florida region in USA [3]. KBDI was also developed to be suitable under Mediterranean conditions, providing accurate results for forestry and fire risk management in Thessaloniki, Northern Greece [44]. Therefore, this study aims to test the behavior of KBDI, modified for peatland wildfires in Central Kalimantan under tropical climate conditions affected by the El Niño disaster in 2015, when the El Niño conditions caused a significant rainfall decline in most parts of Indonesia.

## 2. KBDI Index Modification

### 2.1. KBDI and Wildfire Risk Assessment

KBDI was first introduced to manage forest fire control under a sub-tropical climate. This index represents the net effect of evapotranspiration and precipitation on cumulative moisture deficiency in deep duff or upper soil layers, and is related to the flammability of organic materials in the ground [43]. KBDI is applied to human activity-caused fire and sub-surface fire, and is determined using Eq. (1).

$$KBDI_t = KBDI_{t-1} + DF_t - RF_t, \quad \dots\dots \quad (1)$$

where $DF_t$ is drought factor (mm), $RF_t$ is rainfall factor (mm), $t$ is time (day).

The value of the rainfall factor ($RF_t$) is determined using meteorological data, in the form of annual rainfall and daily rainfall. An $RF_t$ of more than 5.1 mm/day is considered a reduction in the drought index and is determined using the following equation [43].

$$RF_t = \begin{cases} (R_t - 5.1), & \\ & R_t \geq 5.1 \text{ mm/day, 1st rainy day,} \\ R_t, & R_{t-1} \geq 5.1 \text{ mm/day,} \\ & \text{2nd and the next rainy day,} \\ 0, & R_t < 5.1 \text{ mm/day,} \end{cases} \quad (2)$$

where $R_t$ is daily rainfall at $t$ and $R_{t-1}$ is daily rainfall at $t-1$.

The drought factor ($DF_t$) was determined based on the basic theory of soil moisture degradation in the forest area by assuming the following: (1) the field capacity of the organic layer is considered as 203 mm of water in excess of moisture held by the layer at the wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall [43]. The basic formula of $DF_t$ from Eq. (18) of [43] is modified

**Table 1.** Climate variables and the coefficient drought factor.

| Variable | Subtropical | Tropical |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 1270 | 2540 |
| $a$ | 0.9667 | 0.4982 |
| $b$ | 0.0875 | 0.0875 |
| $c$ | 8.30 | 4.27 |
| $w_c$ | 203 | 203 |

with [37] for tropical condition, and [45] for the $a$, $b$, and $c$ coefficients as follows:

$$DF_t = (w_c - KBDI_{t-1}) \frac{\left(ae^{(bTm+1.5552)} - c\right) 10^{-3}}{1 + 10.88e^{(-0.001736R_0)}}, \qquad (3)$$

where $DF_t$ is drought factor (mm), $w_c$ is corresponding field capacity of available water in the layer (mm), $KBDI_{t-1}$ is moisture deficiency (KBDI at $t-1$), $T_m$ is daily maximum air temperature (°C), $t$ is time increment (day), $R_0$ is average annual rainfall (mm), $a$ and $c$ are coefficients influenced by the mean annual rainfall ($R_0$), and $b$ is coefficient influenced by evapotranspiration.

In a sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm, maximum temperature ($T_m$) is 26.67°C, and corresponding field capacity of available water in the layer ($w_c$) is 203 mm [43]. $t_{26.67;R_0}$ from Eq. (13) of [43] gives $t_{26.67;R_0} = 56.41$ days. If $R = \infty$ and $R_0 = 1270$ mm for a subtropical climate, $t_{26.67,\infty}$ from Eq. (16) of [43] gives $t_{26.67,\infty} = 0.4545\,t_{26.67;1270} = 25.64$ days.

[37] modifies the drought-factor formula ($DF_t$) affected by tropical annual rainfall ($R_0$) as 2540 mm, $w_c$, and the temperature used is the same as that in [43], which is 26.67°C. $w_c$ is 203 mm. [37] adjusts the constants $t_{26.67,\infty}$ for a tropical condition from [37] as $t_{26.67,\infty} = 0.8831\,t_{26.67;2540} = 49.87$ days.

The coefficients $a$, $b$, and $c$ for the sub-tropical condition [43] and tropical condition [37] are listed in **Table 1**.

## 2.2. KBDI Index Modification for the Tropical Climate

### 2.2.1. KBDI Index Modification for Tropical Wetland

[37] modified $DF_t$ is affected by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients $a$ and $c$. It was concluded that the loss of evapotranspiration in the tropical climate is 15% higher relative to that in the sub-tropical climate; thus, the coefficient $b$ in **Table 2** become 0.0905 [37]. These coefficients are used as the modifications for the tropical wetland conditions in this paper.

### 2.2.2. KBDI Modified for Tropical Peatlands Followed by El Niño

The formula of $DF_t$ (Eq. (3)) has been developed to represent the average rainfall conditions for wildfire risk control in tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by the El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, as well a reduction in average rainfall [27]. In 2009, the Southern part of Kalimantan received low precipitation, which caused peatland drying and the easy spread of fires [46]. Analysis of rainfall from three stations in the study area indicates that when El Niño occurred in 2015, rainfall decreased by approximately 35% from the annual average rainfall. The annual rainfall in 2015 at the study area was 1650 mm. The evaporation time for the same temperature used by [43] was 26.67°C.

**Table 2.** Climate variables and the coefficient drought factor for tropical wetland and peatland condition.

| Parameter | Tropical wetland | Tropical peatland due to El Niño |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 2540 | 1650 |
| $a$ | 0.4982 | 0.3614 |
| $b$ | 0.0905 | 0.0905 |
| $c$ | 4.27 | 3.10 |
| $w_c$ | 203 | 400 |

In addition to the changes in the coefficients $a$ and $c$ on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 mm of the soil water available for evapotranspiration [43]. The $w_c$ value was on the scale from 0 to 203, where 0 denotes no moisture depletion, and 203 indicates the highest depletion [37]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on peatland research in the Netherlands that used a 400 mm depth for the reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire frequency and the reduction of groundwater level [47]. The Government Regulation of the Republic of Indonesia No. 57 of 2016 on peat ecosystem protection and management, clause 23 point 3, states that peat ecosystems with a cultivation function could be damaged if the water table depth is more than 400 mm below the peat surface [48]. Thus, for the El Niño modifications in this paper, $R_o$ is set as 1650 mm, $T_m$ is 26.67, and $w_c$ is 400. Based on the above concept, adjustment constants using Eqs. (13) and (16) of [43] in tropical peatland gives $t_{26.67;1650} = 111.17$ days and $t_{26.67,\infty} = 0.617\,t_{26.67;1650} = 68.6$ days.

The decrease in rainfall affects the values of the coefficients $a$ and $c$ on $DF_t$ in Eq. (3). The coefficient $b$ used is 0.0905 [37]. **Table 2** shown climate variables for modification 1 (tropical wetland conditions [37]) and modification 2 (tropical peatland conditions due to El Niño) in 2015.

In the previous study, four fire danger classes were used, from 0 to 203 mm [37]. In the present study, the

**Table 3.** Drought index classes of KBDI modified for tropical peatland conditions.

| Classes | KBDI index | KBDI index in tropical peatland |
|---|---|---|
| low | 0–100 | 0–200 |
| moderate | 101–150 | 201–300 |
| high | 151–175 | 301–350 |
| extreme | > 175 | > 350 |

new value of $w_c$ causes a change in the KBDI classes. The water table ranges from 0 to 400 mm. The water table at 400 mm below the surface is considered to cause the maximum drought index and a potential fire risk in the peat ecosystem. A water table of 0 mm, where water is on the surface of the land, is expressed as an ideal peat condition that is always inundated. Based on the new $w_c$ value for the peatland condition, the value of the KBDI classes is corrected. Drought index classes are classified into four levels, as presented in **Table 3**.

## 3. Study Area and Methods

### 3.1. Study Area

The Mega Rice Project consists of one million hectares of peatland in Central Kalimantan and caused damage to the tropical peat forest [49]. It caused the large wildfire in 2015. The highest number of fire alerts (NFA) was recorded on October 19, 2015. The conditions of peatland wildfires in Kalimantan captured by the Moderate Resolution Imaging SpectroRadiometer (MODIS) from the NASA Aqua satellite are illustrated in **Fig. 1**. This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke signals the conditions [50].

The present study was conducted in Block A, the Ex-Mega Rice Project (EMRP) located in Mantangai sub-District, Kapuas District, Central Kalimantan Province, which is illustrated in **Fig. 2(a)** [51]. **Fig. 2(b)** depicts some post-wildfire conditions in the peatland around Block A in November 2015. This area underwent land clearing, which caused the peatland to become dry and flammable. A drought index for peat wildfire risk assessment was evaluated under peat wildfire conditions in 2015.

The largest wildfires occur in tropical peatlands, including the tropical peatland in Indonesia. Peat wildfires have previously occurred in the EMRP area in Central Kalimantan [52]. The Mega Rice Project was started legally on a Presidential decree 82/1995. The project caused 400 thousand ha of tropical rainforest cutting. EMRP was a program that failed considerably to conserve the peatlands in Indonesia [49]. The exploitation of forest and peatland in EMRP land occurred due to the construction of drainage network systems [49]. The drainage network systems divide peat domes, causing massive damage and resulting in the loss of function as field reservoirs, land subsidence, and a decreased water table [53]. This phenomenon causes irreversible peat drying, which triggers forest and peatland wildfires [54]. In addition to the decreased water table, peatland wildfires are caused by the rainfall reduction (the number of dry days), known as the El Niño phenomenon, which usually occurs from September to October.

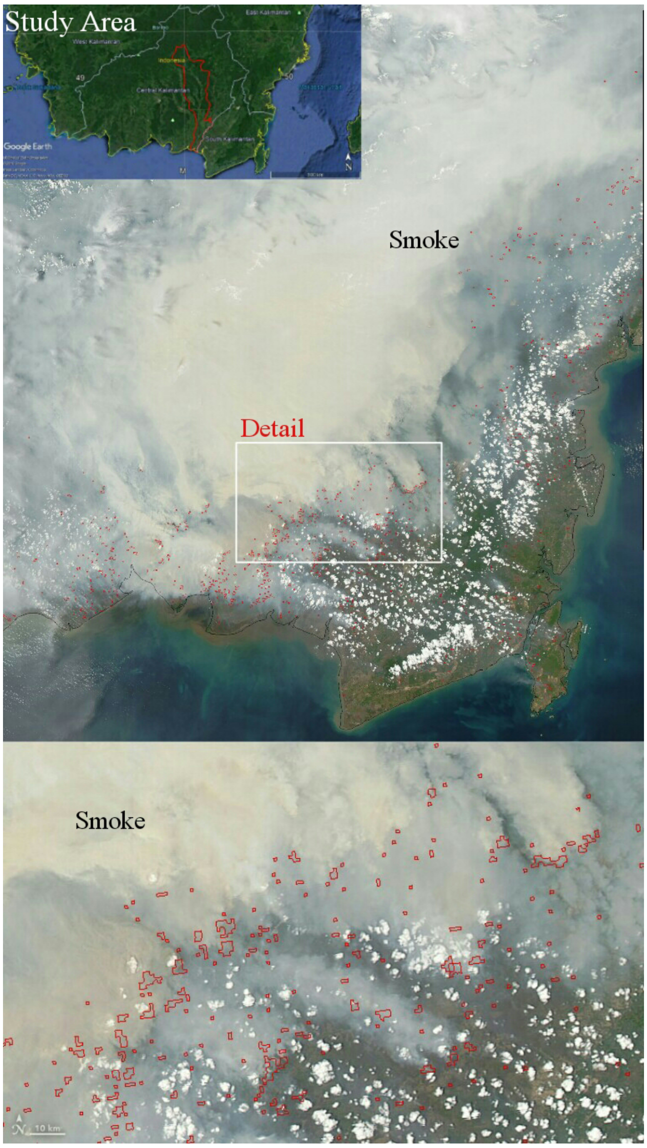



**Fig. 1.** Wildfires hazard was found on October 19, 2015.

Rainfall data was recorded near the study area, such as in Tjilik Riwut, Beringin, and Sanggu Rain Station [55]. Rainfall data was analyzed from 01 January 2015 to 31 December 2015, and there were a total of 263 dry days, which is more than 70% of the total in 2015. The NFA in the form of hotspots were obtained by using NASA's Active Fire Data to determine the possible location of fires. The system uses NASA MODIS satellites, which survey the entire earth every 1–2 days. The sensors on these satellites detect hot marks in infrared spectral waves. Dur-

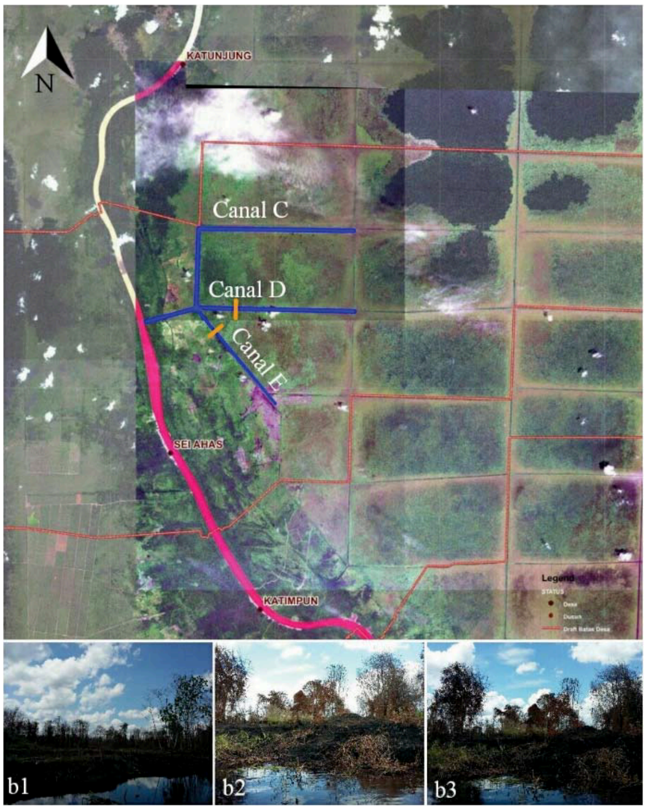



**Fig. 2.** (a) Study area on Block A of Ex-Mega Rice Project and (b) post-wildfire conditions in peatlands around canal C (b1), Canal D post-wildfire (b2), and Canal E post-wildfire (b3) in November 2015.

ing the processing of the satellite imagery, the algorithm looks for a heat sign and detects it as a fire sign. The system can indicate where a fire occurred and can provide a warning of high risk areas [56].

### 3.2. Methods

In this study, a modified KBDI was developed for wildfire risk assessment under tropical peatland conditions influenced by El Niño, with modification to the baseline groundwater conditions for peatland affecting the $w_c$ value. The modified index was compared with KBDI under tropical wetland conditions [37]. The results of the two index modifications were compared against NFA recorded in the peat forest, Block A, Mantangai Subdistrict, Central Kalimantan Province, in 2015.

## 4. Results and Discussion

### 4.1. Rainfall Data

Based on the observations, rainfall from the three rain stations was almost uniform, with an average annual rainfall of 1650 mm in 2015. This rainfall value was below the average annual rainfall of areas with a tropical climate. The mean annual rainfall for areas with a tropical climate ranged from 2000 to 3000 mm [37]. This decrease in rainfall was caused by the El Niño in Indonesia. The average monthly rainfall at the three stations in the study site was the highest (134 mm) in November 2015. The net rainfall or rainfall factor ($RF_t$) was calculated using Eq. (2) to determine the number of dry days (**Table 4**). Dry day conditions were found on 29 days in July, 28 days in August, 30 days in September and 27 days in October 2015.

**Table 4.** Number of dry day and fire alerts.

| | Number of the dry day | Number of fire alerts |
|---|---|---|
| Jan | 9 | 1 |
| Feb | 26 | 0 |
| Mar | 17 | 0 |
| Apr | 17 | 3 |
| May | 23 | 1 |
| Jun | 21 | 1 |
| Jul | 29 | 19 |
| Aug | 28 | 488 |
| Sep | 30 | 1272 |
| Oct | 27 | 1746 |
| Nov | 18 | 10 |
| Dec | 16 | 3 |

### 4.2. Number of Fire Alerts Data

In 2015, there were 30,121 NFA events in the Central Kalimantan Province and 3,544 events in the Mantangai Sub-district. There were 3525 NFA events in Mantangai from July to November 2015, as much as 12.1% from the 29,171 events in Central Kalimantan. NFA increased from July to November 2015, and the largest number of NFA was observed in October 2015, with 1,741 events. This data indicates that the number of fire alerts in October represents half of the NFA for the year 2015, as presented in **Table 4**.

### 4.3. Keetch-Byram Drought Index (KBDI) Analysis

The results of the analysis using $DF_t$, under tropical wetland conditions [37] and under tropical peatland conditions influenced by the El Niño phenomenon are depicted in **Fig. 3**.

**Figure 3** depicts an added line for the beginning of the extreme index, at 175 mm for KBDI modified for the tropical wetland condition, and at 350 mm for KBDI modified for tropical peatland conditions. The KBDI level, with $DF_t$ formula for tropical wetland conditions, for a low index level from 0–100 was 218 values, the moderate index from 101–150 was 42 values, the high drought index from 151–175 was as much as 56 values, and the extreme drought index of more than 175 was 49 values. In the calculation of KBDI, with the modified $DF_t$ formula for tropical peatland conditions including El Niño phenomenon, there were 59 values from the high level,

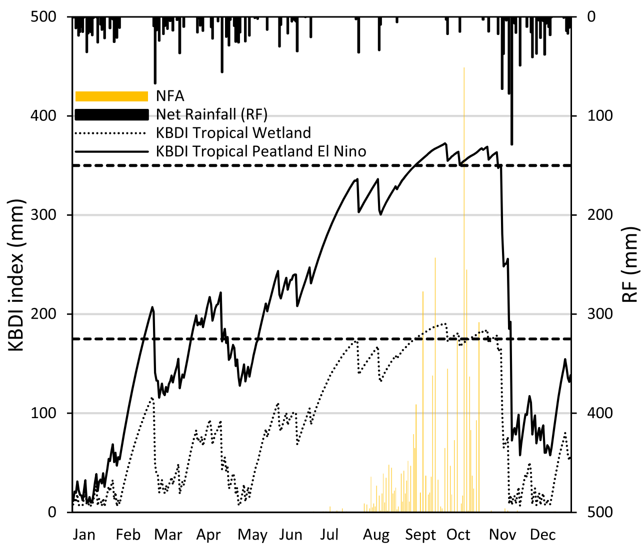



**Fig. 3.** Comparison of KBDI for tropical wetland and the modified KBDI for tropical peatland with the El Niño phenomenon.

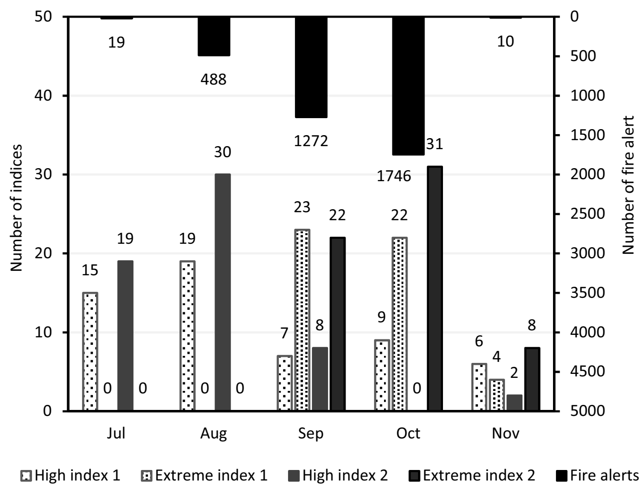



**Fig. 4.** Correlation between Keetch-Byram drought index (KBDI) values and number of fire alerts (NFA).

**Table 5.** Drought level conditions.

| | Wetland conditions | | | | Peatland conditions due to El Niño | | | |
|---|---|---|---|---|---|---|---|---|
| | Low | Mod | High | Extreme | Low | Mod | High | Extreme |
| Jan | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |
| Feb | 23 | 5 | 0 | 0 | 26 | 2 | 0 | 0 |
| Mar | 30 | 1 | 0 | 0 | 30 | 1 | 0 | 0 |
| Apr | 30 | 0 | 0 | 0 | 21 | 9 | 0 | 0 |
| May | 28 | 3 | 0 | 0 | 20 | 11 | 0 | 0 |
| Jun | 25 | 5 | 0 | 0 | 0 | 30 | 0 | 0 |
| Jul | 0 | 16 | 15 | 0 | 0 | 12 | 19 | 0 |
| Aug | 0 | 12 | 19 | 0 | 0 | 1 | 30 | 0 |
| Sep | 0 | 0 | 7 | 23 | 0 | 0 | 8 | 22 |
| Oct | 0 | 0 | 9 | 22 | 0 | 0 | 0 | 31 |
| Nov | 20 | 0 | 6 | 4 | 15 | 5 | 2 | 8 |
| Dec | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |

and the extreme drought conditions increased to 61 occurrences, from July until November 2015. The class index is presented in **Table 5**.

Owing to the 35% reduction in rainfall occurring in the study area in 2015 due to El Niño, and the change in $w_c$ caused by groundwater table change, the extreme drought index increased. High and extreme class results started at the beginning of the dry season from July. In calculating KBDI, with $DF_t$ formula under tropical wetland conditions and tropical peatland conditions, high drought levels began to occur in early July 2015. Extreme drought levels began to occur in September 2015.**Fig. 4** shows the high and extreme classes in KBDI response (with the formula for tropical wetland conditions shown as modification 1, and KBDI with $DF_t$ under tropical peatland conditions including El Niño as modification 2) against fire risk assessment represented by the number of fire alerts.

**Figure 4** shows the high and extreme drought index results from the beginning of July to November 2015, representing the occurrence of fires beginning in July 2015, from KBDI modification for tropical wetland conditions and tropical peatland conditions. Two important findings are:

1. Index response with the $DF_t$ formula for tropical wetland conditions

   Based on the analysis of KBDI with the $DF_t$ formula for tropical wetland conditions, no extreme drought occurred at the beginning of July and August. Extreme drought indices occurred in September 2015 in 23 events, October 2015 in 22 events, and November 2015 in four events. Based on NFA data recorded in July, the study site had 19 fire alerts, followed by 488 fire alerts in August, 1272 fire alerts in September, and 1746 fire alerts in October. The highest level of extreme index results occurred in September 2015.

2. KBDI response to a corrected $DF_t$ for tropical peatland conditions

   In the corrected $DF_t$ formula for tropical peatland conditions affected by El Niño, with a rainfall reduction of 35% with $R_0 = 1650$ mm and groundwater level 400 mm, high to extreme drought levels were observed from September to November 2015, with 61 indices. The results for the extreme drought index were 22 events in September, 31 events in October, and eight events in November 2015. This finding is consistent with the NFA data, where the starting point of fire is in July and the highest number of fire alerts are in October, with 1746 fire alerts. These fire alerts conditions in October 2015 are predicted by extreme drought conditions that cover the whole 31 days of the month.

### 4.4. Discussion

This study was conducted on a peat fire situation in 2015 in Central Kalimantan. This study conducted analysis on KBDI results for data collected in 2015, comparing corrected $DF_t$ modifications for tropical wetland conditions and tropical peatland conditions and the number of fire alerts in Mantangai Sub-district, with the results demonstrating that:

1. The modifications of the KBDI index for tropical peatland conditions adequately represents the real fire risk assessment data recorded in 2015. KBDI modification for tropical peatland conditions increases from the high index level to the extreme index level to the value of 350 and continues to rise to the maximum value of 400 starting on September 9, 2015, representing 109 NFA events that day. KBDI modification for tropical wetland conditions increased from the high index level to the extreme index level on September 9, 2015, represented by 65 fire alerts. These modifications of the KBDI for the conditions of tropical peatlands can demonstrate the potential for fire disasters in the study area.
2. In October 2015, there were 1746 NFA events in Mantangai, with the KBDI modification for tropical peatland conditions resulting in 31 days of extreme indices, while the KBDI wetland modification only resulted in 22 days with extreme indices. According to the modified $DF_t$ for tropical peatland conditions, the extreme class is 12 points higher than KBDI modified for tropical wetland conditions. It rises from September to November 2015 in the study area, with the corrected water table of 400 mm.
3. The highest number of NFA was on October 14, 2015, with 449 fire alerts events represented by the extreme value in KBDI modified for tropical peatland conditions, while the KBDI modified for wetland conditions only resulted in high index results, as shown in **Fig. 3**.
4. The statistical parameter for extreme classes compared against the number of fires from July to November using linear regression for modification 1 gave $R^2$ as 0.828 with $p$-value 0.03. Modification 2 for tropical peatlands gave $R^2$ as 0.829 with $p$-value 0.03. It has been shown that both modifications give a good statistical result.

The modified KBDI for tropical peatland conditions seems to perform better in wildfire risk assessment in the Central Kalimantan during El Niño in 2015 compared with other KBDI formulas. The results follow those of previous Kalimantan Forests and Climate Partnership (KFCP) observations. A study by KFCP from 2004 to 2013 in the same study area showed daily wildfire patterns indicating fires at the same locations and in the same months. Fires occurred from late July to early November. The peak of the fires occurred in September [51]. Previous research from 2001 to 2010 found large-scale land management practices using fire, which caused smoke hazards from mid-August to late October [52]. We can consider the use of the empirical drought index formula for tropical peatland conditions to have several general principles, which are as follows:

1. The KBDI formula must be based on the net rainfall factor set by the $R$ threshold. This threshold for tropical conditions still uses the same threshold as in the previous KBDI formula defined under sub-tropical conditions.
2. Peatland wildfires are not just caused by meteorological conditions but also by many internal factors in the soil, such as peat decomposition, physical properties, water holding capacity [52], and capillarity rise.
3. Peatland wildfires are also affected by unwise peatland management, such as building drainage canals in the peat dome, which results in a change in the water table.

Evaluation of the performance of KBDI under a range of climatic conditions, including a sub-tropical climate, Mediterranean climate, and tropical climate, reports that KBDI is a flexible drought index for almost all climatic conditions and may represent an important tool for forest fire control.

## 5. Conclusion

KBDI modification, by correcting the $DF_t$ formula for the referenced water table level for peatland and with the influence of rainfall reduction due to the El Niño phenomenon, can accurately represent NFA in peatland. The analysis shows the results of the KBDI; drought factor ($DF_t$) correction for tropical peatland conditions, gave an extreme index (375 to 400 mm) occurring from September 9, 2015. Twenty-seven dry days caused 31 days of extreme index, represented by 1746 fire alerts in October 2015. The highest NFA number was on October 14, 2015 with 449 fire alerts events represented with this formula as an extreme value. Therefore, this formula provided satisfactory results in the El Niño conditions of 2015. Further testing is still needed to prove the formula for other El Niño events. In addition to the meteorological and water table factors in the KBDI formula, which affect drought management in peatland, several supporting factors must be considered, such as peat decomposition, physical characteristics, water holding capacity, and capillarity rise. The degraded physical properties of peatlands also lead to larger wildfires with the same number of dry days.

**Acknowledgements**

This study was completed with partial funding from Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) from the DRPM Ditjen Penguatan Riset dan Pengembangan, Ministry of Research, Technology, and High Education – the Republic of Indonesia through LPPM Universitas Gadjah Mada.

**References:**

[1] C. E. Stockwell et al., "Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia, during the 2015 El Niño," Atmos. Chem. Phys., Vol.16, No.18, pp. 11711-11732, 2016.

[2] S. E. Page, F. Siegert, J. O. Rieley, H.-D. V. Boehm, A. Jaya, and S. Limin, "The amount of carbon released from peat and forest fires

in Indonesia during 1997," Nature, Vol.420, No.6911, pp. 61-65, 2002.

[3] W. C. Adinugroho, I. N. N. Suryadiputra, B. H. Saharjo, and L. Siboro, "Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut," Wetlands International: Indonesia Programme, 2004.

[4] H. Hayasaka, "Recent Large-Scale Fires in Boreal and Tropical Forests," J. Disaster Res., Vol.2, No.4, pp. 265-275, DOI: 10.20965/jdr.2007.p0265, 2007.

[5] Wahyunto, S. Ritung, Suparto, and H. Subagjo, "Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan," Wetlands International: Indonesia Programme, 2005.

[6] S. Ritung et al., "Peta Lahan Gambut Indonesia Skala 1:250.000," 2011.

[7] H. Vasander, "3. Overview of types of peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 15-18, 2014.

[8] S. W. Atmojo, "Pengelolaan Lahan Gambut," UNS Press, 2014.

[9] S. Najiyati, L. Muslihat, I. Nyoman, and N. Suryadiputra, "Panduan Pengelolaan Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[10] I. T. C. Wibisono, L. Siboro, and I. N. N. Suryadiputra, "Panduan Rehabilitasi dan Teknik Silvikultur di Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[11] J. P. Andriesse, "Nature and Management of Tropical Peat Soils," FAO Soils Bulletin 59, Food and Agriculture Organization of the United Nations (FAO), 1988.

[12] N. Yulianti and H. Hayasaka, "Recent Active Fires under El Niño Conditions in Kalimantan, Indonesia," American J. of Plant Sciences, Vol.4, No.3A, pp. 685-696, 2013.

[13] S. Page and A. Hooijer, "6. Environmental impacts and consequences of utilizing peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 27-35, 2014.

[14] P. Sofan, Y. Vetrita, F. Yulianto, and M. R. Khomarudin, "Multi-temporal remote sensing data and spectral indices analysis for detection tropical rainforest degradation: case study in Kapuas Hulu and Sintang districts, West Kalimantan, Indonesia," Nat. Hazards, Vol.80, No.2, pp. 1279-1301, 2016.

[15] K. Becek and A. B. Horwath, "Is vegetation collapse on Borneo already in progress?," Nat. Hazards, Vol.85, No.2, pp. 1279-1290, 2017.

[16] H. Herawati and H. Santoso, "Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia," For. Policy Econ., Vol.13, No.4, pp. 227-233, 2011.

[17] A. C. Watts and L. N. Kobziar, "Smoldering Combustion in Organic Soils: Peat and Muck Fires in the Southeastern U.S.," South. Fire Exch., 2012.

[18] A. Sandhyavitri, R. Amri, and D. Fermana, "Development of Underground Peat Fire Detection," Int. Conf. on Technology, Innovation, and Society (ICTIS2019), pp. 439-444, 2016.

[19] X. Huang, F. Restuccia, M. Gramola, and G. Rein, "Experimental study of the formation and collapse of an overhang in the lateral spread of smouldering peat fires," Combust. Flame, Vol.168, pp. 393-402, 2016.

[20] G. Rein, N. Cleaver, C. Ashton, P. Pironi, and J. L. Torero, "The severity of smouldering peat fires and damage to the forest soil," Catena, Vol.74, No.3, pp. 304-309, 2008.

[21] M. G. L. Van Nieuwstadt and D. Sheil, "Drought, fire and tree survival in a Borneo rain forest, East Kalimantan," Indonesia J. of Ecology, Vol.93, No.1, pp. 191-201, 2005.

[22] S. Martín, M. Rodríguez, J. M. Moreno, and D. G. Angeler, "Complex ecological responses to drought and fire-retardant contamination impacts in ephemeral waters," Water. Air. Soil Pollut., Vol.225, No.8, DOI: 10.1007/s11270-014-2078-7, 2014.

[23] M. Solh and M. van Ginkel, "Drought preparedness and drought mitigation in the developing world's drylands," Weather Clim. Extrem., Vol.3, pp. 62-66, 2014.

[24] R. S. Pulwarty and M. V. K. Sivakumar, "Information systems in a changing climate: Early warnings and drought risk management," Weather Clim. Extrem., Vol.3, pp. 14-21, 2014.

[25] M. L. Khandekar, T. S. Murty, D. Scott, and W. Baird, "The 1997 El Niño, Indonesian Forest fires and the Malaysian Smoke problem: A deadly combination of natural and man-made hazard," Nat. Hazards, Vol.21, No.2-3, pp. 131-144, 2000.

[26] R. D. Field, Y. Wang, O. Roswintiarti, and Guswanto, "A drought-based predictor of recent haze events in western Indonesia," Atmos. Environ., Vol.38, No.13, pp. 1869-1878, 2004.

[27] M. Pidwirny, "El Niño, La Niña and the Southern Oscillation," 2006, http://www.physicalgeography.net/fundamentals/7z.html [accessed March 7, 2016]

[28] N. Wanders, H. A. J. van Lanen, and A. F. van Loon, "Indicators for drought characterization on a global scale," WATCH Technical Report No.24, p. 93, 2010.

[29] A. Hasegawa, M. Gusyev, and Y. Iwami, "Meteorological drought and flood assessment using the comparative SPI approach in Asia under climate change," J. Disaster Res., Vol.11, No.6, pp. 1082-1090, DOI: 10.20965/jdr.2016.p1082, 2016.

[30] D. A. Wilhite and M. D. Svoboda, "Drought early warning systems in the context of drought preparedness and mitigation," Early Warn. Syst. drought Prep. drought Manag., pp. 1-21, 2000.

[31] M. A. Gusyev, A. Hasegawa, J. Magome, D. Kuribayashia, H. Sawanoa, and S. Lee, "Drought assessment in the Pampanga River basin, the Philippines – Part 1: Characterizing a role of dams in historical droughts with standardized indices," 21st Int. Congress on Modeling and Simulation, pp. 1586-1592, 2015.

[32] R. A. Adesiji, P. A. Adeoye, and A. O. Gbadebo, "Review Article Effects of Water Table Fluctuations on Peatland-A Review," Sch. J. Eng. Technol., Vol.2, No.3C, pp. 482-487, 2014.

[33] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Pengaruh Karakteristik Gambut Terdegradasi terhadap Kebakaran Lahan Gambut," Prosiding Seminar Nasional Lingkungan Lahan Basah, Vol.3, pp. 347-351, 2018.

[34] R. R. Heim, "A review of twentieth-century drought indices used in the United States," Bulletin of the American Meteorological Society, 2002.

[35] H.-R. Byun and D. A. Wilhite, "Objective Quantification of Drought Severity and Duration," J. of Climate, Vol.12, No.9, pp. 2747-2756, 1999.

[36] World Meteorological Organization (WMO) and Global Water Partnership (GWP), "Handbook of drought indicators and indices," Integrated Drought Management Programme (IDMP), No.1173, 2017.

[37] M. Taufik, B. I. Setiawan, and H. a. J. van Lanen, "Modification of a fire drought index for tropical wetland ecosystems by including water table depth," Agric. For. Meteorol., Vol.203, pp. 1-10, 2015.

[38] D. X. Viegas, G. Bovio, A. Ferreira, A. Nosenzo, and B. Sol, "Comparative study of various methods of fire danger evaluation in southern Europe," Int. J. Wildl. Fire, Vol.9, No.4, p. 235, 1999.

[39] P. Groisman et al., "Changes in Precipitation Distribution Spectra and Contemporary Warming of the Extratropics: Implications for Intense Rainfall, Droughts, and Potential Forest Fire Danger," 16th Conf. on Climate Variability and Change, Session No.12.5, 2005.

[40] C. Willis et al., "The Development of a National Fire Danger Rating System for South Africa," CSIR Water, Environment and Forestry Technology, 2001.

[41] J. Skvarenina, J. Mindas, J. Holecy, and J. Tucek, "Analysis of the natural and meteorological conditions during two largest forest fire events in the Slovak Paradise National Park," J. Meteorol., Vol.7, pp. 167-171, 2003.

[42] A. J. Dowdy, G. a Mills, K. Finkele, and W. De Groot, "Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index," CAWCR Technical Report No.10, 2009.

[43] J. J. Keetch and G. M. Byram, "A Drought Index for Forest Fire Control," U.S. Department of Agriculture, 1968.

[44] G. Petros, M. Antonis, and T. Marianthi, "Development of an adapted empirical drought index to the Mediterranean conditions for use in forestry," Agric. For. Meteorol., Vol.151, No.2, pp. 241-250, 2011.

[45] A. Garcia-Prats, D. C. Antonio, F. J. G. Tarcísio, and M. J. Antonio, "Development of a Keetch and Byram – Based drought index sensitive to forest management in Mediterranean conditions," Agric. For. Meteorol., Vol.205, pp. 40-50, 2015.

[46] K. Kaku and A. Held, "Sentinel Asia: A space-based disaster management support system in the Asia-Pacific region," Int. J. Disaster Risk Reduct., Vol.6, pp. 1-17, 2013.

[47] E. I. Putra, H. Takahashi, H. Hayasaka, and A. Usup, "Recent Peat Fire Activity in the Mega Rice Project Area, Central Kalimantan, Indonesia," J. Disaster Res., Vol.3, No.5, pp. 334-341, DOI: 10.20965/jdr.2008.p0334, 2008.

[48] "Peraturan Pemerintah (PP) No.57: Peraturan Pemerintah (PP) tentang Perubahan atas Peraturan Pemerintah Nomor 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut," 2016.

[49] T. Notohadiprawiro, "Mega-Project of Central Kalimantan Wetland Development for Food Crop Production, Belief and Truth," Proc. of the Int. Peat Symposium: The Spirit of Peatlands, 1998.

[50] NASA, "Earth Observatory," Earth Observatory, 2015, https://earthobservatory.nasa.gov/images/86847/heavy-smoke-blankets-borneo [accessed January 24, 2016]

[51] KFCP, "Peta Rencana Pola Tata Guna Lahan Desa Sei Ahas," Indonesia: Indonesia-Australia Forest Carbon Partnership (IAFCP), 2014.

[52] H. Hayasaka, I. Noguchi, E. Indra, N. Yulianti, and K. Vadrevu, "Peat-fire-related air pollution in Central Kalimantan, Indonesia," Environ. Pollut., Vol.195, pp. 257-266, 2014.

[53] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Restoration of peat dome in ex-Mega rice project area in Central Kalimantan," AIP Conf. Proc., Vol.1977, 2018.

[54] I. N. N. Suryadiputra et al., "2005 Buku_Suryadiputra_Panduan Penyekatan Parit (Indonesia)," Wetlands International: Indonesia Programme, 2005.

[55] BMKG, "Data Hujan Online," 2019, http://dataonline.bmkg.go.id [accessed January 30, 2016]

[56] D. C. Morton, R. S. Defries, J. T. Randerson, L. Giglio, W. Schroeder, and G. R. van der Werf, "Agricultural intensification increases deforestation fire activity in Amazonia," Glob. Chang. Biol., Vol.14, No.10, pp. 2262-2275, 2008.



**Name:**
Novitasari Novitasari

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia


**Brief Career:**
2005- Lecturer, Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat
2015- Student, Civil Engineering Doctoral Program, Universitas Gadjah Mada

**Selected Publications:**
• "Restoration of Peat Dome in Ex-Mega Rice Project Area in Central Kalimantan," American Institute of Physics Conf. Proc., 1977, 040008 (2018), DOI: https://doi.org/10.1063/1.5042978, 2018.

**Academic Societies & Scientific Organizations:**
• Indonesian Association of Hydraulic Engineers (HATHI)
• Indonesia Water Resources Association (JSDA-Indonesia)


**Name:**
Joko Sujono

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia


**Brief Career:**
1989- Lecturer, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "A comparison of techniques for hydrograph recession analysis," Hydrological Processes, Vol.18, No.3, pp. 403-413, 2004.
• "Improving the water productivity of paddy rice (Oryza sativa L.) cultivation through water saving irrigation treatments," Agricultural Sciences, Vol.2, No.4, pp. 511-517, 2011.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Sciences (IAHS)
• Indonesian Association of Hydraulic Engineers (HATHI)


**Name:**
Sri Harto

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia


**Brief Career:**
1994-1997 Dean, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "The characteristics of Unit Hydrographs with different scale of antecedent Soil Moisture Condition," J. of Engineering and Applied Sciences, Vol.11, Issue 12, pp. 2594-2601, 2016.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Science (IAHS)
• International Association of Hydro-Environment Engineering and Research (IAHR)
• Indonesian Association of Hydraulic Engineers (HATHI)

**Name:**
Azwar Maas

**Affiliation:**
Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada

**Address:**
Jl. Flora, Bulak Sumur, Yogyakarta 55281, Indonesia

**Brief Career:**
2012-2016 Head of Soil Science Study Program, Faculty of Agriculture, Universitas Gadjah Mada
2016- Chairman of Expert for Peatland Restoration Agency (BRG)

**Selected Publications:**
- "The tolerance of photosynthesis of some maize cultivars (Zea mays L.) to waterlogging at different stages of growth," Int. J. on Advanced Science, Engineering and Information Technology, Vol.7, Issue 4, pp. 1296-1301, 2017.
- "Characteristics of three biochar types with different pyrolysis time as ameliorant of peat soil," Indian J. of Agricultural Research. Vol.51, Issue 5, pp. 458-462, 2017.

**Academic Societies & Scientific Organizations:**
- Soil Science Sociaty (HIT)
- Indonesian Wild and Land Fires Associate (Karhutra)
- Indonesia Disaster Expert (IABI)

**Name:**
Rachmad Jayadi

**Affiliation:**
Associate Professor, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
2009-2012 Head of Master Program in Natural Disaster Management, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head of Undergraduate Program in Civil Engineering, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
- "Impact of Sedimentation Counter Measure on the Performance of Flood Control: A Case Study of Wonogiri Reservoir," Int. J. of Applied Mechanics and Materials, Vol.881, pp. 78-85, DOI: 10.4028/www.scientific.net/AMM.881.78, 2018.
- "Improving Spatial Rainfall Estimates at Mt. Merapi Area Using Radar-Rain Gauge Conditional Merging," J. Disaster Res., Vol.14 No.1, pp. 69-79, DOI: 10.20965/jdr.2019.p0069, 2019.

**Academic Societies & Scientific Organizations:**
- Indonesian Association of Hydraulic Engineers (HATHI)
- Indonesian National Committee of ICID (INACID)

Gmail **novitasari ST.,MT. <novitasari.st.mt@gmail.com>**

# Fwd: 2nd proof of your paper Dr14-7-9565 (Invoice attached)

**Joko Sujono** <jsujono@ugm.ac.id> 17 September 2019 pukul 10.42
Kepada: Novitasari Novitasari <novitasari.st.mt@mail.ugm.ac.id>
Cc: "novitasari ST.,MT." <novitasari.st.mt@gmail.com>

---------- Forwarded message ---------
From: **JDR Editorial Office** <disaster@fujipress.jp>
Date: Tue, 17 Sep 2019, 09:40
Subject: 2nd proof of your paper Dr14-7-9565 (Invoice attached)
To: Joko Sujono <jsujono@ugm.ac.id>

Dear Dr. Joko Sujono,

Thank you very much for your prompt reply and hard work.

We have attached the proof of your paper Dr14-7-9565 and an invoice to this e-mail.
Now your corrections have been included.
Please check it and return your corrections, if any.

==================
> 2. At the 1st paragraph of Section 3.1, there are the words "the red
> line" (in Fig.1),
-> dark shapes
Thank you for your modification.
However, this modification may be unsuitable for the online full-colored PDF.
As I have no idea of suitable words for both situations,
I suggest to left the first expression "the red line."
I'm sorry for troubling you.

> 4. Please provide us detailed information of
Refs.[27][39][40][49][55].
Thank you for your information.
I have added further information to that you provided.
==================

Please respond within TWO DAYS (by Sep 19) from receipt of
this message even if you have no corrections.
If no response is received from the author, the publisher
will proceed by assuming that there are no further corrections to be made.

Thank you for your cooperation.

Best regards,

Aya Kamata
JDR Editorial Office

Fuji Technology Press Ltd.

Unizo Uchikanda 1-Chome Bldg. 2F
1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
Phone: +81-3-5577-3851
Fax: +81-3-5577-3861
E-mail: disaster@fujipress.jp

HP[OPEN ACCESS Journal] URL: https://www.fujipress.jp/jdr/dr/
*Create your account (free) for download full-texts for free at :
https://www.fujipress.jp/usces-member/?page=newmember (free)
*Latest issue: https://www.fujipress.jp/jdr/dr/
*Call for papers: https://www.fujipress.jp/category/cfp/?journal=jsstr
---------------------Please cite JDR papers - JDR is now applying to
SCI---------------------
*JDR is indexed in SCOPUS and Compendex (Ei)
*JACIII, JRM, JDR are indexed in ESCI
*JDR is an OPEN ACCESS journal and you can download the all full-texts
published in IJAT for free by free registration (No registration fee is
required).
Registration can be made at :
URL: https://www.fujipress.jp/usces-member/?page=newmember
--------------------------------------------------------------------------------

On 2019/09/16 14:06, Joko Sujono wrote:
> Dear Aya Kamata
> JDR Editorial Office
> Fuji Technology Press Ltd.
>
> I thank you for the PDF proof read and the comment.
> I have made a correction on the PDF file and provide more high quality
> file of Fig.1 as attached.
> Thank you very much for your kindness.
> Best regards,
> joko sujono
>
> On Sun, 15 Sep 2019 at 15:40, JDR Editorial Office
> <disaster@fujipress.jp <mailto:disaster@fujipress.jp>> wrote:
>
> Dear Dr. Joko Sujono,
>
> The proof of your article, to be published in
> the Journal of Disaster Research
> Vol.14 No.7, has been prepared.
> Please download the PDF file from the following:
>
> https://box.fujipress.com/index.php/s/wGLLF02aGX5JIKg
>
> Please proof-read it and return your corrections.
> Acceptable at this stage are corrections about layout,
> spelling mistakes, wrong cross-references, and
> mistakes or updating in references.
>
> Please use Acrobat to edit the PDF file
> by adding "post-it" type notes,
> and return it via e-mail to disaster@fujipress.jp
> <mailto:disaster@fujipress.jp>.
> If this is not possible, please print out the PDF file
> and write down the corrections and any other comments on it.
> Then, send it to us by FAX (+81-3-5577-3861) or
> scan it to create a PDF file and send it to us via e-mail.
>
> If changes are minimal, you can alternatively return the corrections
> via e-mail, explaining where they occur in the paper
> (page number and line) and specifying both the old (wrong) version
> and the correction.
>
> =================
> The following questions have arisen during the preparation
> of your proof. Please answer them.

>
> 1. Resolution of Fig. 1 is low.
> Please send a high-resolution image if you have.
>
> 2. At the 1st paragraph of Section 3.1, there are the words "the red
> line" (in Fig.1), but the color can not be distinguished when
> printed in
> black and white.
> Please change other expression without colors, or apply color printing
> (JPY21000 per printed page).
> (The article PDF published online will be full color for free.)
>
> 3. Please inform us the accessed date of Ref.[50].
>
> 4. Please provide us detailed information of Refs.[27][39][40][49][55].
> For example, a publisher if it's a book, a journal title if a journal
> article, URL and an accessed date if a website.
> ==================
>
> No further publication processing will occur until this proof is
> returned.
> Please respond by **September 17** in order to publish it on October
> issue.
>
> Please note that this is your last chance to modify your paper.
> The corrected version will be sent to you before publication.
>
> Thank you for your cooperation.
>
> Sincerely yours,
>
> Aya Kamata
> JDR Editorial Office
>
> Fuji Technology Press Ltd.
>
> Unizo Uchikanda 1-Chome Bldg. 2F
> 1-15-7 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan
> Phone: +81-3-5577-3851
> Fax: +81-3-5577-3861
> E-mail: disaster@fujipress.jp <mailto:disaster@fujipress.jp>

>
>
> p.s.
> To view and print the PDF article you will need Acrobat Reader from
> Adobe. This program is freely available and can be downloaded from
> http://www.adobe.com/products/acrobat/readstep2.html.
> To edit the PDF files, you need Acrobat which is not free.
> Please consult the manual of Acrobat for how to edit the PDF documents.
>

**2 lampiran**

**INV_dr14_7_956500.pdf**
78K

**Dr14-7-9565.pdf**
3632K

**Paper: Dr14-7-9565;**

# Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia During El Niño Phenomenon

**Novitasari Novitasari*, Joko Sujono*,†, Sri Harto*, Azwar Maas**, and Rachmad Jayadi***

*Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Jl. Grafika No 2, Yogyakarta 55281, Indonesia
†Corresponding author, E-mail: jsujono@ugm.ac.id
**Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia
[Received August 1, 2018; accepted September 4, 2019]

**Peatland wildfires, especially in tropical ecosystems, are often caused by drought, and lead to smoke and other related problems in all aspects of community life in Indonesia, especially in Central Kalimantan. Drought is worsened by the number of dry days in the dry season, known as the El Niño phenomenon, and the drainage system in a peatland. Additionally, drought decreases the water table and increases the probability of occurrence of wildfires in peatland areas. This study aims to modify the numerical formula of the drought factor ($DF_t$) in the Keetch–Byram drought index (KBDI) based on tropical peatland wildfire conditions in Central Kalimantan during the El Niño phenomenon in 2015. Furthermore, it applies a revised peatland water table reference of 400 mm below the ground surface, based on previous research and the Government regulation on peatland ecosystem protection and management in Indonesia. These El Niño conditions caused a rain decline of approximately 35% in Block A, Ex-Mega Rice Project, Mantangai sub-District, Kapuas District, Central Kalimantan Province. The modified KBDI is compared with the Number of Fire Alerts (NFA) using NASA's Active Fire Data in 2015. The analysis results demonstrate that the modified $DF_t$ under tropical peatland conditions leads to an increase in the drought index value, beginning on the driest days between July and November 2015. The value of the KBDI drought index increases from the high to the extreme index from September to November 2015, when as many as 61 extreme drought indices became indicators for peatland wildfire risk assessment. The extreme KBDI is directly proportional to the NFA recorded during 2015, and the highest number of fire alerts is observed for October 2015, with 1746 fire alerts within 31 days and extreme drought indices from 27 days. Hence, this modified formula is suitable for wildfire conditions on this peatland in Central Kalimantan. Overall, the modified $DF_t$ can be successfully applied to the El Niño phenomenon in 2015.**

**Keywords:** Keetch–Byram drought index (KBDI), number of fire alerts, El Niño, water table, peatland wildfire

## 1. Introduction

The forest wildfires of 2015 were the largest wildfires in Indonesia for the last ten years in terms of the amounts of trace gases and aerosols released, which have been monitored in several previous studies [1]. The severity of theses wildfires was similar to the disaster that occurred in 1997 [2]. Forest wildfires in Indonesia not only occur in upland environments but also in wetlands [3]. These forest wildfires mainly occur in tropical peatlands [4]. Wildfires in tropical peatlands occupy an area equivalent to 10.8% of Indonesia's land area [5]. Among tropical countries, Indonesia has the largest area of tropical peatland, which is approximately 14 million ha and is mainly found in Sumatra, Kalimantan, and Papua [6]. Indonesia's peatland is a part of the wider tropical peatland habitat in Southeast Asia [7]. Tropical peat comprises accumulated organic materials in a wetland ecosystem [8]. Tropical peat is formed in forests under wetland conditions with the production of large quantities of organic materials [9, 10].

Indonesia's peatland has been developed by the building drainage systems. Canals are intended to decrease the water table in the peatland. These canals are utilized to support the cultivation of crops, such as oil palm and acacia. The resulting decrease in the water table can cause the peat to become overdrained and thereby make it flammable, damaging the ecological balance and eliminating forest and peatland biodiversity [10]. Peatland is commonly burned to minimize production cost; however, this practice may cause uncontrolled peatland wildfires [11]. In addition to human-caused fires, peatland wildfires are caused by meteorological drought factors, such as a lack of rainfall and high evaporation rate [12]. Dry peatland, which is fundamentally unstable, loses water from the soil, allowing oxygen to penetrate the pores and oxidize the peat through biological and chemical processes [13]. Peatland wildfires not only cause rainforest degradation [14] and affect biodiversity [15], but also release smoke and carbon emissions to the atmosphere; fire harms nearby communities and leads to the loss of lives and property [16]. Peatland wildfires slowly spread through the surface, and those classified as smoldering fires are absorbed by the subsurface and organic lay-

ers [17]. This type of fire is difficult to detect [18]. Smoldering wildfire causes the lateral spread of flames under different moisture and wind conditions [19] and creates strong smoke that spreads over extensive areas [20]. Drought and fires are important components for the assessment of the dynamics of tropical peat forests [21].

The risk of wildfires increases as the frequency and duration of drought increases [22]. Natural drought is a condition that cannot be managed [23] and has affected millions of square kilometers of land in many areas, such as North America, West Africa, and East Asia [24]. In Indonesia, drought in peatlands leads to sub-surface wildfires all around the ecosystem. These wildfires cause smoke to spread to other countries, such as Malaysia [25]. Fires occur almost every year in Indonesia during the dry season. Wildfires usually occur between June and September and intensify during El Niño [26]. El Niño is a natural phenomenon characterized by the warming of temperatures in the Pacific Ocean and causes drought in the Asian region [27]. El Niño decreases the amount of rainfall in Indonesia [16].

A situation with lower than average water availability due to climate variability may cause drought [28]. The limitations for drought have not yet been widely agreed upon, which indicates that drought is a region specific event. However, there are several types of drought that can be used as reference. A decreased amount of rainfall is also one of the causes of drought, namely, meteorological drought [29]. This type of drought appears in various components of the hydrological cycle [30]. Drought is not only caused by meteorological factors (lack of precipitation), but also by agricultural (lack of soil moisture), hydrological (lack of river discharge and dam inflows), and socio-economic (lack of water supply to meet water demand) factors [29, 31].

In Indonesia, meteorological drought is often accompanied by dry peatland caused by the decline in the water table and changes in the physical properties of peat due to the drainage system. Some fires are also caused by human activities, such as land clearing. The blocking of canals can reduce the degradation of peatlands to a larger extent [32]. Additionally, it can also help to maintain the water table [33] to prevent drought on peatlands.

The process by which drought leads to wildfires is a complex process, and a drought index cannot be easily specified. No index can fully explain the complexity of drought and its impacts [34]. A drought index can be used as an indicator to determine the classification of the drought level of a particular region or area [28]. Many drought indices have been expanded to appraise the scale, type, and impact of drought [35]. Many drought indices are easy to build and use, based on meteorology data, soil moisture, hydrology, and remote sensing [36]. One formula that uses meteorological data is the standardized precipitation index (SPI) [29] and the Keetch–Byram drought index (KBDI) [37].

Some drought indices are built for specific uses and environments. In forestry, many drought indices are designed for fire risk assessment [38]. The most widely used drought indices are the Nesterov index, Zhdanko index [39], Angstrom index [40], Baumgartner index [41], McArthur forest fire danger index [42], and KBDI [43]. KBDI is one of the most widely used indices for forest fire management under various climatic conditions [2, 34]. KBDI was first developed for forest fire management in the sub-tropical Florida region in USA [3]. KBDI was also developed to be suitable under Mediterranean conditions, providing accurate results for forestry and fire risk management in Thessaloniki, Northern Greece [44]. Therefore, this study aims to test the behavior of KBDI, modified for peatland wildfires in Central Kalimantan under tropical climate conditions affected by the El Niño disaster in 2015, when the El Niño conditions caused a significant rainfall decline in most parts of Indonesia.

## 2. KBDI Index Modification

### 2.1. KBDI and Wildfire Risk Assessment

KBDI was first introduced to manage forest fire control under a sub-tropical climate. This index represents the net effect of evapotranspiration and precipitation on cumulative moisture deficiency in deep duff or upper soil layers, and is related to the flammability of organic materials in the ground [43]. KBDI is applied to human activity-caused fire and sub-surface fire, and is determined using Eq. (1).

$$KBDI_t = KBDI_{t-1} + DF_t - RF_t, \quad \ldots\ldots \quad (1)$$

where

$DF_t$ = drought factor (mm),
$RF_t$ = rainfall factor (mm),
$t$ = time (day).

The value of the rainfall factor ($RF_t$) is determined using meteorological data, in the form of annual rainfall and daily rainfall. An $RF_t$ of more than 5.1 mm/day is considered a reduction in the drought index and is determined using the following equation [43].

$$RF_t = \begin{cases} (R_t - 5.1), & \\ & R_t \geq 5.1 \text{ mm/day, 1st rainy day}, \\ R_t, & R_{t-1} \geq 5.1 \text{ mm/day}, \\ & \text{2nd and the next rainy day}, \\ 0, & R_t < 5.1 \text{ mm/day}, \end{cases} \quad (2)$$

where

$R_t$ = daily rainfall at $t$,
$R_{t-1}$ = daily rainfall at $t-1$.

The drought factor ($DF_t$) was determined based on the basic theory of soil moisture degradation in the forest area by assuming the following: (1) the field capacity of the organic layer is considered as 203 mm of water in excess of moisture held by the layer at the wilting point; (2) the organic soil layer obtains moisture from rainfall and loses moisture from evapotranspiration, and the lowest moisture level is detected at the wilting point; (3) the rate of evapotranspiration is a function of meteorological variables and vegetation density, and (4) the vegetation density is a function of the mean annual rainfall [43]. The basic formula of $DF_t$ from Eq. (18) of [43] is modified with [37] for tropical condition, and [45] for the $a$, $b$, and $c$ coefficients as follows:

$$DF_t = (w_c - KBDI_{t-1}) \frac{\left(ae^{(bTm+1.5552)} - c\right) 10^{-3}}{1 + 10.88e^{(-0.001736R_0)}}, \quad (3)$$

where

$DF_t$ = drought factor (mm),
$w_c$ = corresponding field capacity of available water in the layer (mm),
$KBDI_{t-1}$ = moisture deficiency (KBDI at $t-1$),
$Tm$ = daily maximum air temperature (°C),
$t$ = time increment (day),
$R_0$ = average annual rainfall (mm),
$a$ and $c$ = coefficient influenced by the mean annual rainfall ($R_0$),
$b$ = coefficient influenced by evapotranspiration.

In a sub-tropical climate, the average annual rainfall $R_0$ is 1270 mm, maximum temperature ($T_m$) is 26.67°C, and corresponding field capacity of available water in the layer ($w_c$) is 203 mm [43]. $t_{26.67;R_0}$ from Eq. (13) of [43] gives $t_{26.67;R_0} = 56.41$ days. If $R = \infty$ and $R_0 = 1270$ mm for a subtropical climate, $t_{26.67,\infty}$ from Eq. (16) of [43] gives $t_{26.67,\infty} = 0.4545\, t_{26.67;1270} = 25.64$ days.

[37] modifies the drought-factor formula ($DF_t$) affected by tropical annual rainfall ($R_0$) as 2540 mm, $w_c$, and the temperature used is the same as that in [43], which is 26.67°C. $w_c$ is 203 mm. [37] adjusts the constants $t_{26.67,\infty}$ for a tropical condition from [37] as $t_{26.67,\infty} = 0.8831\, t_{26.67;2540} = 49.87$ days.

The coefficients $a$, $b$, and $c$ for the sub-tropical condition [43] and tropical condition [37] are listed in **Table 1**.

## 2.2. KBDI Index Modification for the Tropical Climate

### 2.2.1. KBDI Index Modification for Tropical Wetland

[37] modified $DF_t$ is affected by annual rainfall and evapotranspiration in a tropical climate through changing the values of the coefficients $a$ and $c$. It was concluded that the loss of evapotranspiration in the tropical climate is 15% higher relative to that in the sub-tropical climate; thus, the coefficient $b$ in **Table 2** become 0.0905 [37]. These coefficients are used as the modifications for the tropical wetland conditions in this paper.

**Table 1.** Climate variables and the coefficient drought factor.

| Variable | Subtropical | Tropical |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 1270 | 2540 |
| $a$ | 0.9667 | 0.4982 |
| $b$ | 0.0875 | 0.0875 |
| $c$ | 8.30 | 4.27 |
| $w_c$ | 203 | 203 |

**Table 2.** Climate variables and the coefficient drought factor for tropical wetland and peatland condition.

| Parameter | Tropical wetland | Tropical peatland due to El Niño |
|---|---|---|
| $T_m$ [°C] | 26.67 | 26.67 |
| $R_0$ [mm] | 2540 | 1650 |
| $a$ | 0.4982 | 0.3614 |
| $b$ | 0.0905 | 0.0905 |
| $c$ | 4.27 | 3.10 |
| $w_c$ | 203 | 400 |

### 2.2.2. KBDI Modified for Tropical Peatlands Followed by El Niño

The formula of $DF_t$ (Eq. (3)) has been developed to represent the average rainfall conditions for wildfire risk control in tropical wetland ecosystems. However, wildfires in tropical forests, especially those in Indonesia's tropical forests, are also affected by the El Niño phenomenon, which causes extreme warming to the equatorial Pacific. El Niño causes severe droughts in Australia, Indonesia, India, and South Africa, as well a reduction in average rainfall [27]. In 2009, the Southern part of Kalimantan received low precipitation, which caused peatland drying and the easy spread of fires [46]. Analysis of rainfall from three stations in the study area indicates that when El Niño occurred in 2015, rainfall decreased by approximately 35% from the annual average rainfall. The annual rainfall in 2015 at the study area was 1650 mm. The evaporation time for the same temperature used by [43] was 26.67°C.

In addition to the changes in the coefficients $a$ and $c$ on $DF_t$, $w_c$ was also modified. In the initial equation of KBDI, the $w_c$ value is assumed to be 203 mm of the soil water available for evapotranspiration [43]. The $w_c$ value was on the scale from 0 to 203, where 0 denotes no moisture depletion, and 203 indicates the highest depletion [37]. The $w_c$ value is influenced by the depth of the reference water table. This value was based on peatland research in the Netherlands that used a 400 mm depth for the reference water table to avoid peat subsidence [11]. Peat dryness correlated with wildfire frequency and the reduction of groundwater level [47]. The Government Regulation of the Republic of Indonesia No. 57 of 2016 on peat ecosystem protection and management, clause 23

**Table 3.** Drought index classes of KBDI modified for tropical peatland conditions.

| Classes | KBDI index | KBDI index in tropical peatland |
|---|---|---|
| low | 0–100 | 0–200 |
| moderate | 101–150 | 201–300 |
| high | 151–175 | 301–350 |
| extreme | $> 175$ | $> 350$ |

point 3, states that peat ecosystems with a cultivation function could be damaged if the water table depth is more than 400 mm below the peat surface [48]. Thus, for the El Niño modifications in this paper, $R_o$ is set as 1650 mm, $T_m$ is 26.67, and $w_c$ is 400. Based on the above concept, adjustment constants using Eqs. (13) and (16) of [43] in tropical peatland gives $t_{26.67;1650} = 111.17$ days and $t_{26.67,\infty} = 0.617\, t_{26.67;1650} = 68.6$ days.

The decrease in rainfall affects the values of the coefficients $a$ and $c$ on $DF_t$ in Eq. (3). The coefficient $b$ used is 0.0905 [37]. **Table 2** shown climate variables for modification 1 (tropical wetland conditions [37]) and modification 2 (tropical peatland conditions due to El Niño) in 2015.

In the previous study, four fire danger classes were used, from 0 to 203 mm [37]. In the present study, the new value of $w_c$ causes a change in the KBDI classes. The water table ranges from 0 to 400 mm. The water table at 400 mm below the surface is considered to cause the maximum drought index and a potential fire risk in the peat ecosystem. A water table of 0 mm, where water is on the surface of the land, is expressed as an ideal peat condition that is always inundated. Based on the new $w_c$ value for the peatland condition, the value of the KBDI classes is corrected. Drought index classes are classified into four levels, as presented in **Table 3**.

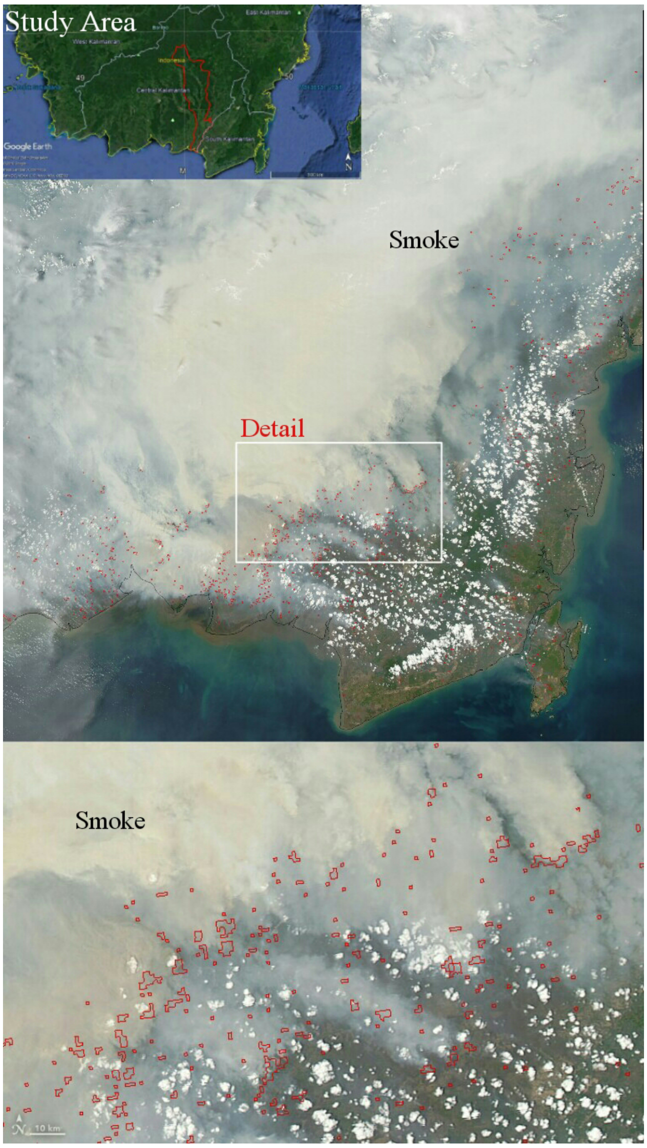



**Fig. 1.** Wildfires hazard was found on October 19, 2015.

## 3. Study Area and Methods

### 3.1. Study Area

The Mega Rice Project consists of one million hectares of peatland in Central Kalimantan and caused damage to the tropical peat forest [49]. It caused the large wildfire in 2015. The highest number of fire alerts (NFA) was recorded on October 19, 2015. The conditions of peatland wildfires in Kalimantan captured by the Moderate Resolution Imaging SpectroRadiometer (MODIS) from the NASA Aqua satellite are illustrated in **Fig. 1**. This image was taken on October 19, 2015; the red line indicates a hot spot where the sensors detected unusually warm surface temperatures associated with fires, and gray smoke signals the conditions [50].

The present study was conducted in Block A, the Ex-Mega Rice Project (EMRP) located in Mantangai sub-District, Kapuas District, Central Kalimantan Province, which is illustrated in **Fig. 2(a)** [51]. **Fig. 2(b)** depicts some post-wildfire conditions in the peatland around Block A in November 2015. This area underwent land clearing, which caused the peatland to become dry and flammable. A drought index for peat wildfire risk assessment was evaluated under peat wildfire conditions in 2015.

The largest wildfires occur in tropical peatlands, including the tropical peatland in Indonesia. Peat wildfires have previously occurred in the EMRP area in Central Kalimantan [52]. The Mega Rice Project was started legally on a Presidential decree 82/1995. The project caused 400 thousand ha of tropical rainforest cutting. EMRP was a program that failed considerably to conserve the peatlands in Indonesia [49]. The exploitation of forest and peatland in EMRP land occurred due to the construction of drainage network systems [49]. The drainage network systems divide peat domes, causing massive damage and resulting in the loss of function as field reservoirs, land subsidence, and a decreased water table [53]. This

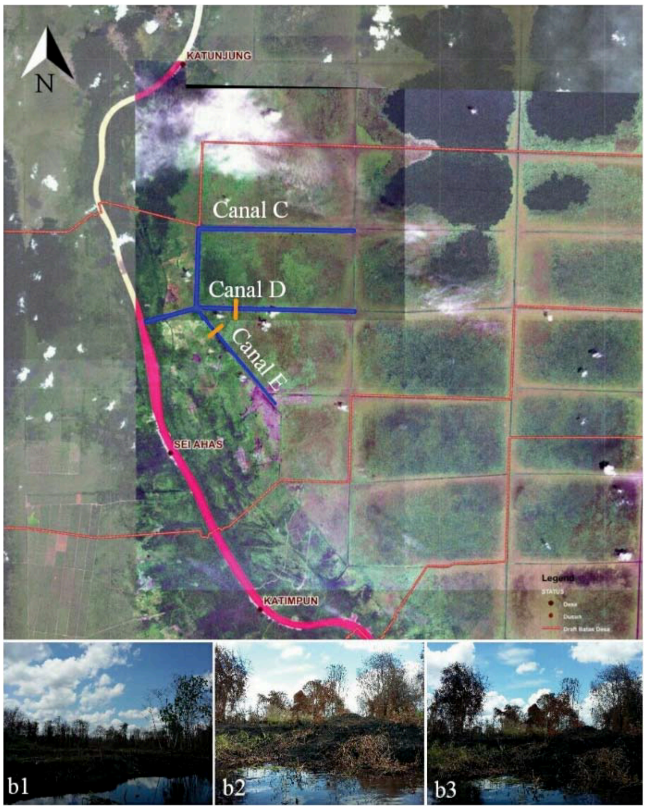



**Fig. 2.** (a) Study area on Block A of Ex-Mega Rice Project and (b) post-wildfire conditions in peatlands around canal C (b1), Canal D post-wildfire (b2), and Canal E post-wildfire (b3) in November 2015.

phenomenon causes irreversible peat drying, which triggers forest and peatland wildfires [54]. In addition to the decreased water table, peatland wildfires are caused by the rainfall reduction (the number of dry days), known as the El Niño phenomenon, which usually occurs from September to October.

Rainfall data was recorded near the study area, such as in Tjilik Riwut, Beringin, and Sanggu Rain Station [55]. Rainfall data was analyzed from 01 January 2015 to 31 December 2015, and there were a total of 263 dry days, which is more than 70% of the total in 2015. The NFA in the form of hotspots were obtained by using NASA's Active Fire Data to determine the possible location of fires. The system uses NASA MODIS satellites, which survey the entire earth every 1–2 days. The sensors on these satellites detect hot marks in infrared spectral waves. During the processing of the satellite imagery, the algorithm looks for a heat sign and detects it as a fire sign. The system can indicate where a fire occurred and can provide a warning of high risk areas [56].

### 3.2. Methods

In this study, a modified KBDI was developed for wildfire risk assessment under tropical peatland conditions influenced by El Niño, with modification to the baseline groundwater conditions for peatland affecting the

**Table 4.** Number of dry day and fire alerts.

| | Number of the dry day | Number of fire alerts |
|---|---|---|
| Jan | 9 | 1 |
| Feb | 26 | 0 |
| Mar | 17 | 0 |
| Apr | 17 | 3 |
| May | 23 | 1 |
| Jun | 21 | 1 |
| Jul | 29 | 19 |
| Aug | 28 | 488 |
| Sep | 30 | 1272 |
| Oct | 27 | 1746 |
| Nov | 18 | 10 |
| Dec | 16 | 3 |

$w_c$ value. The modified index was compared with KBDI under tropical wetland conditions [37]. The results of the two index modifications were compared against NFA recorded in the peat forest, Block A, Mantangai Sub-district, Central Kalimantan Province, in 2015.

## 4. Results and Discussion

### 4.1. Rainfall Data

Based on the observations, rainfall from the three rain stations was almost uniform, with an average annual rainfall of 1650 mm in 2015. This rainfall value was below the average annual rainfall of areas with a tropical climate. The mean annual rainfall for areas with a tropical climate ranged from 2000 to 3000 mm [37]. This decrease in rainfall was caused by the El Niño in Indonesia. The average monthly rainfall at the three stations in the study site was the highest (134 mm) in November 2015. The net rainfall or rainfall factor ($RF_t$) was calculated using Eq. (2) to determine the number of dry days (**Table 4**). Dry day conditions were found on 29 days in July, 28 days in August, 30 days in September and 27 days in October 2015.

### 4.2. Number of Fire Alerts Data

In 2015, there were 30,121 NFA events in the Central Kalimantan Province and 3,544 events in the Mantangai Sub-district. There were 3525 NFA events in Mantangai from July to November 2015, as much as 12.1% from the 29,171 events in Central Kalimantan. NFA increased from July to November 2015, and the largest number of NFA was observed in October 2015, with 1,741 events. This data indicates that the number of fire alerts in October represents half of the NFA for the year 2015, as presented in **Table 4**.

### 4.3. Keetch-Byram Drought Index (KBDI) Analysis

The results of the analysis using $DF_t$, under tropical wetland conditions [37] and under tropical peatland con-

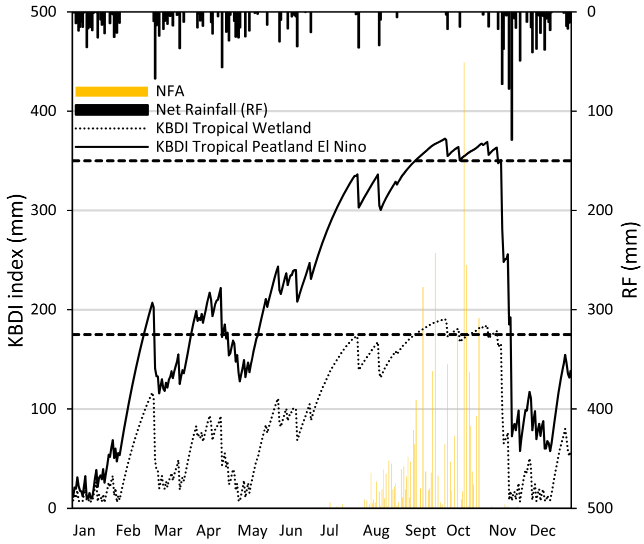



**Fig. 3.** Comparison of KBDI for tropical wetland and the modified KBDI for tropical peatland with the El Niño phenomenon.

**Table 5.** Drought level conditions.

| | Wetland conditions | | | | Peatland conditions due to El Niño | | | |
|---|---|---|---|---|---|---|---|---|
| | Low | Mod | High | Extreme | Low | Mod | High | Extreme |
| Jan | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |
| Feb | 23 | 5 | 0 | 0 | 26 | 2 | 0 | 0 |
| Mar | 30 | 1 | 0 | 0 | 30 | 1 | 0 | 0 |
| Apr | 30 | 0 | 0 | 0 | 21 | 9 | 0 | 0 |
| May | 28 | 3 | 0 | 0 | 20 | 11 | 0 | 0 |
| Jun | 25 | 5 | 0 | 0 | 0 | 30 | 0 | 0 |
| Jul | 0 | 16 | 15 | 0 | 0 | 12 | 19 | 0 |
| Aug | 0 | 12 | 19 | 0 | 0 | 1 | 30 | 0 |
| Sep | 0 | 0 | 7 | 23 | 0 | 0 | 8 | 22 |
| Oct | 0 | 0 | 9 | 22 | 0 | 0 | 0 | 31 |
| Nov | 20 | 0 | 6 | 4 | 15 | 5 | 2 | 8 |
| Dec | 31 | 0 | 0 | 0 | 31 | 0 | 0 | 0 |

ditions influenced by the El Niño phenomenon are depicted in **Fig. 3**.

**Figure 3** depicts an added line for the beginning of the extreme index, at 175 mm for KBDI modified for the tropical wetland condition, and at 350 mm for KBDI modified for tropical peatland conditions. The KBDI level, with $DF_t$ formula for tropical wetland conditions, for a low index level from 0–100 was 218 values, the moderate index from 101–150 was 42 values, the high drought index from 151–175 was as much as 56 values, and the extreme drought index of more than 175 was 49 values. In the calculation of KBDI, with the modified $DF_t$ formula for tropical peatland conditions including El Niño phenomenon, there were 59 values from the high level, and the extreme drought conditions increased to 61 occurrences, from July until November 2015. The class index is presented in **Table 5**.

Owing to the 35% reduction in rainfall occurring in the

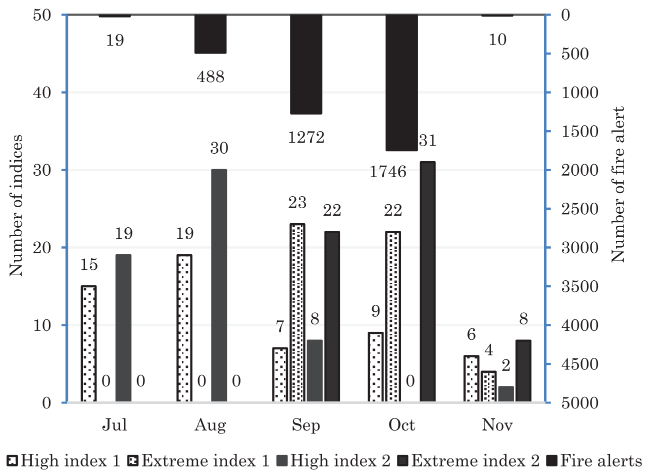



**Fig. 4.** Correlation between Keetch-Byram drought index (KBDI) values and number of fire alerts (NFA).

study area in 2015 due to El Niño, and the change in $w_c$ caused by groundwater table change, the extreme drought index increased. High and extreme class results started at the beginning of the dry season from July. In calculating KBDI, with $DF_t$ formula under tropical wetland conditions and tropical peatland conditions, high drought levels began to occur in early July 2015. Extreme drought levels began to occur in September 2015.**Fig. 4** shows the high and extreme classes in KBDI response (with the formula for tropical wetland conditions shown as modification 1, and KBDI with $DF_t$ under tropical peatland conditions including El Niño as modification 2) against fire risk assessment represented by the number of fire alerts.

**Figure 4** shows the high and extreme drought index results from the beginning of July to November 2015, representing the occurrence of fires beginning in July 2015, from KBDI modification for tropical wetland conditions and tropical peatland conditions. Two important findings are:

1. Index response with the $DF_t$ formula for tropical wetland conditions

   Based on the analysis of KBDI with the $DF_t$ formula for tropical wetland conditions, no extreme drought occurred at the beginning of July and August. Extreme drought indices occurred in September 2015 in 23 events, October 2015 in 22 events, and November 2015 in four events. Based on NFA data recorded in July, the study site had 19 fire alerts, followed by 488 fire alerts in August, 1272 fire alerts in September, and 1746 fire alerts in October. The highest level of extreme index results occurred in September 2015.

2. KBDI response to a corrected $DF_t$ for tropical peatland conditions

   In the corrected $DF_t$ formula for tropical peatland conditions affected by El Niño, with a rainfall reduction of 35% with $R_0 = 1650$ mm and groundwater level 400 mm, high to extreme drought levels were observed from September to November 2015, with 61 indices. The results for the extreme drought index were 22 events in September, 31 events in October, and eight events in November 2015. This finding is consistent with the NFA data, where the starting point of fire is in July and the highest number of fire alerts are in October, with 1746 fire alerts. These fire alerts conditions in October 2015 are predicted by extreme drought conditions that cover the whole 31 days of the month.

### 4.4. Discussion

This study was conducted on a peat fire situation in 2015 in Central Kalimantan. This study conducted analysis on KBDI results for data collected in 2015, comparing corrected $DF_t$ modifications for tropical wetland conditions and tropical peatland conditions and the number of fire alerts in Mantangai Sub-district, with the results demonstrating that:

1. The modifications of the KBDI index for tropical peatland conditions adequately represents the real fire risk assessment data recorded in 2015. KBDI modification for tropical peatland conditions increases from the high index level to the extreme index level to the value of 350 and continues to rise to the maximum value of 400 starting on September 9, 2015, representing 109 NFA events that day. KBDI modification for tropical wetland conditions increased from the high index level to the extreme index level on September 9, 2015, represented by 65 fire alerts. These modifications of the KBDI for the conditions of tropical peatlands can demonstrate the potential for fire disasters in the study area.
2. In October 2015, there were 1746 NFA events in Mantangai, with the KBDI modification for tropical peatland conditions resulting in 31 days of extreme indices, while the KBDI wetland modification only resulted in 22 days with extreme indices. According to the modified $DF_t$ for tropical peatland conditions, the extreme class is 12 points higher than KBDI modified for tropical wetland conditions. It rises from September to November 2015 in the study area, with the corrected water table of 400 mm.
3. The highest number of NFA was on October 14, 2015, with 449 fire alerts events represented by the extreme value in KBDI modified for tropical peatland conditions, while the KBDI modified for wetland conditions only resulted in high index results, as shown in **Fig. 3**.
4. The statistical parameter for extreme classes compared against the number of fires from July to November using linear regression for modification 1 gave $R^2$ as 0.828 with $p$-value 0.03. Modification 2 for tropical peatlands gave $R^2$ as 0.829 with $p$-value 0.03. It has been shown that both modifications give a good statistical result.

The modified KBDI for tropical peatland conditions seems to perform better in wildfire risk assessment in the Central Kalimantan during El Niño in 2015 compared with other KBDI formulas. The results follow those of previous Kalimantan Forests and Climate Partnership (KFCP) observations. A study by KFCP from 2004 to 2013 in the same study area showed daily wildfire patterns indicating fires at the same locations and in the same months. Fires occurred from late July to early November. The peak of the fires occurred in September [51]. Previous research from 2001 to 2010 found large-scale land management practices using fire, which caused smoke hazards from mid-August to late October [52]. We can consider the use of the empirical drought index formula for tropical peatland conditions to have several general principles, which are as follows:

1. The KBDI formula must be based on the net rainfall factor set by the $R$ threshold. This threshold for tropical conditions still uses the same threshold as in the previous KBDI formula defined under sub-tropical conditions.
2. Peatland wildfires are not just caused by meteorological conditions but also by many internal factors in the soil, such as peat decomposition, physical properties, water holding capacity [52], and capillarity rise.
3. Peatland wildfires are also affected by unwise peatland management, such as building drainage canals in the peat dome, which results in a change in the water table.

Evaluation of the performance of KBDI under a range of climatic conditions, including a sub-tropical climate, Mediterranean climate, and tropical climate, reports that KBDI is a flexible drought index for almost all climatic conditions and may represent an important tool for forest fire control.

## 5. Conclusion

KBDI modification, by correcting the $DF_t$ formula for the referenced water table level for peatland and with the influence of rainfall reduction due to the El Niño phenomenon, can accurately represent NFA in peatland. The analysis shows the results of the KBDI; drought factor ($DF_t$) correction for tropical peatland conditions, gave an extreme index (375 to 400 mm) occurring from September 9, 2015. Twenty-seven dry days caused 31 days of extreme index, represented by 1746 fire alerts in October 2015. The highest NFA number was on October 14, 2015 with 449 fire alerts events represented with this formula as an extreme value. Therefore, this formula provided satisfactory results in the El Niño conditions of 2015. Further testing is still needed to prove the formula for other El Niño events. In addition to the meteorological and water table factors in the KBDI formula, which affect drought management in peatland, several supporting factors must be considered, such as peat decomposition, physical characteristics, water holding capacity, and capillarity rise. The degraded physical properties of peatlands also lead to larger wildfires with the same number of dry days.

**Acknowledgements**

This study was completed with partial funding from Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) from the DRPM Ditjen Penguatan Riset dan Pengembangan, Ministry of Research, Technology, and High Education – the Republic of Indonesia through LPPM Universitas Gadjah Mada.

**References:**

[1] C. E. Stockwell et al., "Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia, during the 2015 El Niño," Atmos. Chem. Phys., Vol.16, No.18, pp. 11711-11732, 2016.

[2] S. E. Page, F. Siegert, J. O. Rieley, H.-D. V. Boehm, A. Jaya, and S. Limin, "The amount of carbon released from peat and forest fires in Indonesia during 1997," Nature, Vol.420, No.6911, pp. 61-65, 2002.

[3] W. C. Adinugroho, I. N. N. Suryadiputra, B. H. Saharjo, and L. Siboro, "Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut," Wetlands International: Indonesia Programme, 2004.

[4] H. Hayasaka, "Recent Large-Scale Fires in Boreal and Tropical Forests," J. Disaster Res., Vol.2, No.4, pp. 265-275, DOI: 10.20965/jdr.2007.p0265, 2007.

[5] Wahyunto, S. Ritung, Suparto, and H. Subagjo, "Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan," Wetlands International: Indonesia Programme, 2005.

[6] S. Ritung et al., "Peta Lahan Gambut Indonesia Skala 1:250.000," 2011.

[7] H. Vasander, "3. Overview of types of peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 15-18, 2014.

[8] S. W. Atmojo, "Pengelolaan Lahan Gambut," UNS Press, 2014.

[9] S. Najiyati, L. Muslihat, I. Nyoman, and N. Suryadiputra, "Panduan Pengelolaan Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[10] I. T. C. Wibisono, L. Siboro, and I. N. N. Suryadiputra, "Panduan Rehabilitasi dan Teknik Silvikultur di Lahan Gambut," Wetlands International: Indonesia Programme, 2005.

[11] J. P. Andriesse, "Nature and Management of Tropical Peat Soils," FAO Soils Bulletin 59, Food and Agriculture Organization of the United Nations (FAO), 1988.

[12] N. Yulianti and H. Hayasaka, "Recent Active Fires under El Niño Conditions in Kalimantan, Indonesia," American J. of Plant Sciences, Vol.4, No.3A, pp. 685-696, 2013.

[13] S. Page and A. Hooijer, "6. Environmental impacts and consequences of utilizing peatlands," R. Biancalani and A. Avagyan (Eds.), "Towards climate-responsible peatlands management," Food and Agriculture Organization of the United Nations (FAO), pp. 27-35, 2014.

[14] P. Sofan, Y. Vetrita, F. Yulianto, and M. R. Khomarudin, "Multitemporal remote sensing data and spectral indices analysis for detection tropical rainforest degradation: case study in Kapuas Hulu and Sintang districts, West Kalimantan, Indonesia," Nat. Hazards, Vol.80, No.2, pp. 1279-1301, 2016.

[15] K. Becek and A. B. Horwath, "Is vegetation collapse on Borneo already in progress?," Nat. Hazards, Vol.85, No.2, pp. 1279-1290, 2017.

[16] H. Herawati and H. Santoso, "Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia," For. Policy Econ., Vol.13, No.4, pp. 227-233, 2011.

[17] A. C. Watts and L. N. Kobziar, "Smoldering Combustion in Organic Soils: Peat and Muck Fires in the Southeastern U.S.," South. Fire Exch., 2012.

[18] A. Sandhyavitri, R. Amri, and D. Fermana, "Development of Underground Peat Fire Detection," Int. Conf. on Technology, Innovation, and Society (ICTIS2019), pp. 439-444, 2016.

[19] X. Huang, F. Restuccia, M. Gramola, and G. Rein, "Experimental study of the formation and collapse of an overhang in the lateral spread of smouldering peat fires," Combust. Flame, Vol.168, pp. 393-402, 2016.

[20] G. Rein, N. Cleaver, C. Ashton, P. Pironi, and J. L. Torero, "The severity of smouldering peat fires and damage to the forest soil," Catena, Vol.74, No.3, pp. 304-309, 2008.

[21] M. G. L. Van Nieuwstadt and D. Sheil, "Drought, fire and tree survival in a Borneo rain forest, East Kalimantan," Indonesia J. of Ecology, Vol.93, No.1, pp. 191-201, 2005.

[22] S. Martín, M. Rodríguez, J. M. Moreno, and D. G. Angeler, "Complex ecological responses to drought and fire-retardant contamination impacts in ephemeral waters," Water. Air. Soil Pollut., Vol.225, No.8, DOI: 10.1007/s11270-014-2078-7, 2014.

[23] M. Solh and M. van Ginkel, "Drought preparedness and drought mitigation in the developing world's drylands," Weather Clim. Extrem., Vol.3, pp. 62-66, 2014.

[24] R. S. Pulwarty and M. V. K. Sivakumar, "Information systems in a changing climate: Early warnings and drought risk management," Weather Clim. Extrem., Vol.3, pp. 14-21, 2014.

[25] M. L. Khandekar, T. S. Murty, D. Scott, and W. Baird, "The 1997 El Niño, Indonesian Forest fires and the Malaysian Smoke problem: A deadly combination of natural and man-made hazard," Nat. Hazards, Vol.21, No.2-3, pp. 131-144, 2000.

[26] R. D. Field, Y. Wang, O. Roswintiarti, and Guswanto, "A drought-based predictor of recent haze events in western Indonesia," Atmos. Environ., Vol.38, No.13, pp. 1869-1878, 2004.

[27] M. Pidwirny, "El Niño, La Niña and the Southern Oscillation," 2006, http://www.physicalgeography.net/fundamentals/7z.html [accessed March 7, 2016]

[28] N. Wanders, H. A. J. van Lanen, and A. F. van Loon, "Indicators for drought characterization on a global scale," WATCH Technical Report No.24, p. 93, 2010.

[29] A. Hasegawa, M. Gusyev, and Y. Iwami, "Meteorological drought and flood assessment using the comparative SPI approach in Asia under climate change," J. Disaster Res., Vol.11, No.6, pp. 1082-1090, DOI: 10.20965/jdr.2016.p1082, 2016.

[30] D. A. Wilhite and M. D. Svoboda, "Drought early warning systems in the context of drought preparedness and mitigation," Early Warn. Syst. drought Prep. drought Manag., pp. 1-21, 2000.

[31] M. A. Gusyev, A. Hasegawa, J. Magome, D. Kuribayashia, H. Sawanoa, and S. Lee, "Drought assessment in the Pampanga River basin, the Philippines – Part 1: Characterizing a role of dams in historical droughts with standardized indices," 21st Int. Congress on Modeling and Simulation, pp. 1586-1592, 2015.

[32] R. A. Adesiji, P. A. Adeoye, and A. O. Gbadebo, "Review Article Effects of Water Table Fluctuations on Peatland-A Review," Sch. J. Eng. Technol., Vol.2, No.3C, pp. 482-487, 2014.

[33] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Pengaruh Karakteristik Gambut Terdegradasi terhadap Kebakaran Lahan Gambut," Prosiding Seminar Nasional Lingkungan Lahan Basah, Vol.3, pp. 347-351, 2018.

[34] R. R. Heim, "A review of twentieth-century drought indices used in the United States," Bulletin of the American Meteorological Society, 2002.

[35] H.-R. Byun and D. A. Wilhite, "Objective Quantification of Drought Severity and Duration," J. of Climate, Vol.12, No.9, pp. 2747-2756, 1999.

[36] World Meteorological Organization (WMO) and Global Water Partnership (GWP), "Handbook of drought indicators and indices," Integrated Drought Management Programme (IDMP), No.1173, 2017.

[37] M. Taufik, B. I. Setiawan, and H. a. J. van Lanen, "Modification of a fire drought index for tropical wetland ecosystems by including water table depth," Agric. For. Meteorol., Vol.203, pp. 1-10, 2015.

[38] D. X. Viegas, G. Bovio, A. Ferreira, A. Nosenzo, and B. Sol, "Comparative study of various methods of fire danger evaluation in southern Europe," Int. J. Wildl. Fire, Vol.9, No.4, p. 235, 1999.

[39] P. Groisman et al., "Changes in Precipitation Distribution Spectra and Contemporary Warming of the Extratropics: Implications for Intense Rainfall, Droughts, and Potential Forest Fire Danger," 16th Conf. on Climate Variability and Change, Session No.12.5, 2005.

[40] C. Willis et al., "The Development of a National Fire Danger Rating System for South Africa," CSIR Water, Environment and Forestry Technology, 2001.

[41] J. Skvarenina, J. Mindas, J. Holecy, and J. Tucek, "Analysis of the natural and meteorological conditions during two largest forest fire events in the Slovak Paradise National Park," J. Meteorol., Vol.7, pp. 167-171, 2003.

[42] A. J. Dowdy, G. a Mills, K. Finkele, and W. De Groot, "Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index Australian fire weather as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index," CAWCR Technical Report No.10, 2009.

[43] J. J. Keetch and G. M. Byram, "A Drought Index for Forest Fire Control," U.S. Department of Agriculture, 1968.

[44] G. Petros, M. Antonis, and T. Marianthi, "Development of an adapted empirical drought index to the Mediterranean conditions for use in forestry," Agric. For. Meteorol., Vol.151, No.2, pp. 241-250, 2011.

[45] A. Garcia-Prats, D. C. Antonio, F. J. G. Tarcísio, and M. J. Antonio, "Development of a Keetch and Byram – Based drought index sensitive to forest management in Mediterranean conditions," Agric. For. Meteorol., Vol.205, pp. 40-50, 2015.

[46] K. Kaku and A. Held, "Sentinel Asia: A space-based disaster management support system in the Asia-Pacific region," Int. J. Disaster Risk Reduct., Vol.6, pp. 1-17, 2013.

[47] E. I. Putra, H. Takahashi, H. Hayasaka, and A. Usup, "Recent Peat Fire Activity in the Mega Rice Project Area, Central Kalimantan, Indonesia," J. Disaster Res., Vol.3, No.5, pp. 334-341, DOI: 10.20965/jdr.2008.p0334, 2008.

[48] "Peraturan Pemerintah (PP) No.57: Peraturan Pemerintah (PP) tentang Perubahan atas Peraturan Pemerintah Nomor 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut," 2016.

[49] T. Notohadiprawiro, "Mega-Project of Central Kalimantan Wetland Development for Food Crop Production, Belief and Truth," Proc. of the Int. Peat Symposium: The Spirit of Peatlands, 1998.

[50] NASA, "Earth Observatory," Earth Observatory, 2015, https://earthobservatory.nasa.gov/images/86847/heavy-smoke-blankets-borneo [accessed January 24, 2016]

[51] KFCP, "Peta Rencana Pola Tata Guna Lahan Desa Sei Ahas," Indonesia: Indonesia-Australia Forest Carbon Partnership (IAFCP), 2014.

[52] H. Hayasaka, I. Noguchi, E. Indra, N. Yulianti, and K. Vadrevu, "Peat-fire-related air pollution in Central Kalimantan, Indonesia," Environ. Pollut., Vol.195, pp. 257-266, 2014.

[53] N. Novitasari, J. Sujono, S. Harto, A. Maas, and R. Jayadi, "Restoration of peat dome in ex-Mega rice project area in Central Kalimantan," AIP Conf. Proc., Vol.1977, 2018.

[54] I. N. N. Suryadiputra et al., "2005 Buku_Suryadiputra_Panduan Penyekatan Parit (Indonesia)," Wetlands International: Indonesia Programme, 2005.

[55] BMKG, "Data Hujan Online," 2019, http://dataonline.bmkg.go.id [accessed January 30, 2016]

[56] D. C. Morton, R. S. Defries, J. T. Randerson, L. Giglio, W. Schroeder, and G. R. van der Werf, "Agricultural intensification increases deforestation fire activity in Amazonia," Glob. Chang. Biol., Vol.14, No.10, pp. 2262-2275, 2008.

**Name:**
Novitasari Novitasari

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
2005- Lecturer, Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat
2015- Student, Civil Engineering Doctoral Program, Universitas Gadjah Mada

**Selected Publications:**
• "Restoration of Peat Dome in Ex-Mega Rice Project Area in Central Kalimantan," American Institute of Physics Conf. Proc., 1977, 040008 (2018), DOI: https://doi.org/10.1063/1.5042978, 2018.

**Academic Societies & Scientific Organizations:**
• Indonesian Association of Hydraulic Engineers (HATHI)
• Indonesia Water Resources Association (JSDA-Indonesia)

**Name:**
Joko Sujono

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
1989- Lecturer, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "A comparison of techniques for hydrograph recession analysis," Hydrological Processes, Vol.18, No.3, pp. 403-413, 2004.
• "Improving the water productivity of paddy rice (Oryza sativa L.) cultivation through water saving irrigation treatments," Agricultural Sciences, Vol.2, No.4, pp. 511-517, 2011.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Sciences (IAHS)
• Indonesian Association of Hydraulic Engineers (HATHI)

**Name:**
Sri Harto

**Affiliation:**
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
1994-1997 Dean, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "The characteristics of Unit Hydrographs with different scale of antecedent Soil Moisture Condition," J. of Engineering and Applied Sciences, Vol.11, Issue 12, pp. 2594-2601, 2016.

**Academic Societies & Scientific Organizations:**
• International Association of Hydrological Science (IAHS)
• International Association of Hydro-Environment Engineering and Research (IAHR)
• Indonesian Association of Hydraulic Engineers (HATHI)

**Name:**
Azwar Maas

**Affiliation:**
Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada

**Address:**
Jl. Flora, Bulak Sumur, Yogyakarta 55281, Indonesia

**Brief Career:**
2012-2016 Head of Soil Science Study Program, Faculty of Agriculture, Universitas Gadjah Mada
2016- Chairman of Expert for Peatland Restoration Agency (BRG)

**Selected Publications:**
• "The tolerance of photosynthesis of some maize cultivars (Zea mays L.) to waterlogging at different stages of growth," Int. J. on Advanced Science, Engineering and Information Technology, Vol.7, Issue 4, pp. 1296-1301, 2017.
• "Characteristics of three biochar types with different pyrolysis time as ameliorant of peat soil," Indian J. of Agricultural Research. Vol.51, Issue 5, pp. 458-462, 2017.

**Academic Societies & Scientific Organizations:**
• Soil Science Sociaty (HIT)
• Indonesian Wild and Land Fires Associate (Karhutra)
• Indonesia Disaster Expert (IABI)

**Name:**
Rachmad Jayadi

**Affiliation:**
Associate Professor, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Address:**
Jl. Grafika 2, Yogyakarta 55281, Indonesia

**Brief Career:**
2009-2012 Head of Master Program in Natural Disaster Management, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada
2016- Head of Undergraduate Program in Civil Engineering, Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada

**Selected Publications:**
• "Impact of Sedimentation Counter Measure on the Performance of Flood Control: A Case Study of Wonogiri Reservoir," Int. J. of Applied Mechanics and Materials, Vol.881, pp. 78-85, DOI: 10.4028/www.scientific.net/AMM.881.78, 2018.
• "Improving Spatial Rainfall Estimates at Mt. Merapi Area Using Radar-Rain Gauge Conditional Merging," J. Disaster Res., Vol.14 No.1, pp. 69-79, DOI: 10.20965/jdr.2019.p0069, 2019.

**Academic Societies & Scientific Organizations:**
• Indonesian Association of Hydraulic Engineers (HATHI)
• Indonesian National Committee of ICID (INACID)

No: 956500

# INVOICE

September 17, 2019

Universitas Gadjah Mada

Fuji Technology Press Ltd.

Unizo Uchikanda 1-chome bldg.,
1-15-7 Uchikanda, Chiyoda-ku,
Tokyo 101-0047, Japan
Tel: +81-3-5577-3851
Fax: +81-3-5577-3861
Email: disaster@fujipress.jp

| No. | Description | Quant. | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | Journal of Disaster Research Vol.14, No.7, 10 pages | | | | |
| 2 | Page Charge | 10 | page | 12,000 | 120,000 |
| | | | | Total | 120,000 |

(Currency: JPY)

ID: 9565

Title: Drought Index for Peatland Wildfire Management in Central Kalimantan, Indonesia during El Niño Phenomenon

Authors: Novitasari Novitasari, Joko Sujono, Sri Harto, Azwar Maas, and Rachmad Jayadi

Due date: October 17, 2019

1) Online payment by credit card - Visa,MC,AmEx,JCB,or DSF - or by Paypal.
   Please visit our website at the following URL. The page is protected by password.
   https://www.fujipress.jp/item/dr1479565
   Password: 95650904

2) Bank Transfer

| | |
|---|---|
| Bank/branch: | RAKUTEN BANK, LTD. Head Office |
| Branch address: | 1-14-1 Tamagawa, Setagaya-ku, Tokyo, JAPAN |
| SWIFT code: | RAKTJPJT |
| Account number: | 251-7206558 |
| Account holder: | FUJI TECHNOLOGY PRESS LTD. |

Please also specify the intermediary Bank as follows.
Sumitomo Mitsui Banking Corporation, Tokyo, JAPAN (SWIFT code: SMBCJPJT)