# 3rd World Irrigation Forum

1-7 September 2019, Bali, Indonesia

## Full Papers of WIF3
## and
## International Workshops

# Development for
# Water, Food and Nutrition Security in a Competitive Environment

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE
COMMISSION INTERNATIONALE DES IRRIGATIONS ET DU DRAINAGE

# 3rd WIF 2019

## Theme:
## Development for Water, Food and Nutrition Security in a Competitive Environment

International Commission on Irrigation and Drainage (ICID)

Organized by:

ICID•CIID

International Commission on Irrigation and Drainage (ICID)

INACID

Hosted by:

Indonesian National Committee of ICID (INACID)
Ministry of Public Works and Housing
Directorate General of Water Resources
SDA Buiding, 8th Floor,Jalan Pattimura No. 20
Kebayoran Baru, Jakarta Selatan 12110
Republic of Indonesia

Supported by :

Ministry of Public Works and Housing; Ministry of Agriculture; Ministry of National Development Planning; Ministry of Foreign Affairs; Ministry of Tourism; and Provincial Government of Bali, Republic of Indonesia

The International Commission on Irrigation and Drainage (ICID), established in 1950 is the leading scientific, technical and not-for-profit Non-Governmental Organization (NGO). ICID, through its network of professionals spread across more than a hundred countries, has facilitated sharing of experiences and transfer of water management technology for over half-a-century. ICID supports capacity development, stimulates research and innovation and strives to promote policies and programs to enhance sustainable development of irrigated agriculture through a comprehensive water management framework.

**ISBN No. 978-81-89610-27-2**



**August 2019**

THIRD WORLD IRRIGATION FORUM

1-7 September 2019, Bali, Indonesia

# CONTENTS

# WELCOME

Dear Friends,

On behalf of the Indonesian National Committee of International Commission on Irrigation and Drainage (INACID), I would like to welcome all the members and distinguished participants of the 3rd World Irrigation Forum (WIF3), which will be followed by the 70th International Executive Council (IEC) Meeting to Bali, Indonesia. Indonesia has the distinguished honor of being a founder member country when ICID was established in the year 1950. We sincerely welcome you all again, for the 3rd time, after the 49th IEC at Sanur- Bali in 1998 and 61st IEC and 6th Asian Regional conference at Yogyakarta in 2010.

Indonesia is the largest archipelago in the world, consisting of about 17,541 islands. The territory of Indonesia is 5,2 million km2 with 1,9 million km2 of which is the mainland. However, “food security” remains a challenge for the burgeoning population of Indonesia. Given above, the Forum has come to Indonesia at right time to look for solutions to alleviate the food security. The main theme of the WIF3 “Development for water, food and nutrition security in a competitive environment” is very appropriate for exploring new innovative ways for better food security.

The venue of the event “Bali” is known for its picturesque landscape of paddy fields and rice terraces. The integrated rice-field irrigation system of Bali, Indonesia, called “Subak” has been known to the world for centuries. Bali possesses an important cultural historical heritage, including Subak Landscape of the Pakerisan watershed and the royal temple of the Taman Ayun that have been determined as the world cultural and natural heritage. There are also a vast number of Balinese performing art featured throughout the province including the classical Kecak dance, gamelan music and popular fire dance, not to mention the Endek Bali, a traditional heritage dress with unique pattern.

I believe that through this important event, we will be able to show you the whole set of our experiences in implementing the country’s development particularly in irrigation and drainage fields, and the water resources development in general. Therefore, it is a great honor for us to host this important Forum and welcome you to Bali. We shall render every effort to make the most of these events meaningful, enjoyable and memorable to the participants and their accompanying persons.

In closing, may I inform you that the people of Bali are looking forward to welcoming and embracing you and your family as part of our family, not only during the Forum, but also for the subsequent holiday enjoyments now and in the years to come.

**Ir. Adang Saf Ahmad**
President, INACID

# FOREWORD

Dear Colleagues,

The current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to a new united nations report (2017). Most of the addition will be in developing countries, and the exponential growth in population would require doubling the current food production. Regionally, the population in Asia will nearly double to over 4 billion (47%) people in 2025. This has led the world, especially the Asian continent, face some serious challenges in water, food, and energy sector due to incessant growth of population, leading to environmental degradation and numerous other global issues which are simultaneously affecting our water resources development and management. Sustainable development as envisaged under ICID

Vision 2030, under limiting natural resources, calls for recognizing the interlinkages between various sectors. Given above, the main theme of the 3rd World Irrigation Forum (WIF3) is chosen as “Development for water, food and nutrition security in a competitive environment”, which is further divided into three subthemes.

A clear understanding of interlinkages such as nexus between water, food and energy (Sub theme 1 of the Forum) requires greater interaction between stakeholders from all the sectors (Sub theme 2 of the Forum) and generate a better understanding and coordination mechanisms among different disciplines. Such an approach can only improve the water and energy productivity in agriculture to ensure rural transformation (Sub theme 3 of the Forum). The third Forum will provide an opportunity for the actors in these sectors to come together and develop pathways to sustainable development.

The pre-Forum proceedings provide background papers on these Sub themes and abstracts of papers with an electronic version (USB) containing all full length papers. I am confident that this volume will help you in your active participation in various technical sessions of the Forum. Apart from the technical sessions, there would be fourteen Supporting Events organized by various international partners, a Ministerial and Senior Officers’ Roundtable and Farmers Roundtable, Six International workshops and Young professional training sessions. The International Exhibition along with the WIF3 is sure to provide a rich experience providing multi-disciplinary perspective.

We wish you all a successful Third World Irrigation Forum.

**Eng. Felix B Reinders**
President, ICID

# PREFACE

Dear Colleagues,

The triennial World Irrigation Forum (WIF) aims to bring together all the stakeholders involved in agricultural water management at all levels, including the policy makers, experts, research institutions, non-governmental organizations and farmers. It provides a platform for the world irrigation community to find solutions to problems plaguing the irrigated agriculture, in time of depleting freshwater resources as a result of global warming and climate change.

Accordingly, WIF3, hosted by Indonesian National Committee of ICID (INACID) in cooperation with ICID is being organized in partnership with ADB, FAO, IWMI, World bank and many other International Partners during 1-7 September 2019 at Bali, Indonesia. The main theme of WIF3 is "Development for water, food and nutrition security in a competitive environment" with three Sub-themes as : 1. Enabling policy environment for water, food and energy; 2. Role of civil society and NGOs with focus on farmers and extension facilities; and 3. Improving agricultural water productivity with focus on rural transformation are part of this publication. Background papers were prepared by experts representing various stakeholders with a view to present the global perspectives on the above three sub-themes. My special thanks are due to Mr. Jelle Beekma (ADB), Dr. Olcay Unver (Vice-Chair, UN-Water, FAO) and Mr. IJsbrand H. de Jong (World Bank) and their teams for preparing these knowledge rich background papers. More than 300 abstracts were received on various sub-themes, which were reviewed and finally 191 papers have been incorporated in the Forum proceeding. These papers will be presented during the Forum in several parallel sessions and poster sessions and the issues emerging from the sub-themes would be discussed in the plenary session and presented as Forum statement during closing session of WIF3.

In order to facilitate the discussions during the various Forum sessions, this pre-Forum proceeding has been placed in your hands which includes the abstracts of all accepted papers/posters and a USB containing all the full length papers including the Background Papers of the sub-themes. Many other experts / professionals offered their valuable time at the request of the International Technical Advisory Committee (ITAC) to act as International Reviewers of more than 300 abstract received. My profuse thanks are due to each member of the International Review committee for their time and efforts in reviewing the abstracts/papers.

Besides deliberating on the technical papers presented, the Forum provides opportunity for participation of policy makers, planners, famers, youth and the industry. Accordingly the Forum includes a Ministerial and Senior Officers' Roundtable and a Farmers' Roundtable, YP Training, Supporting Events and International Exhibition.

Last but not the least, my special appreciation to the Central Office team consisting of Dr. Vijay K. Labhsetwar, as a Mentor, Er. B. A. Chivate Director (Tech), Mr. Madhu Mohanan, Communication Officer and Mr. Keshav Dev Tanwar, Assistant IT Officer and other supporting staff for their dedication in bringing this volume to you on time. My special thanks are also due to Dr. T. B. S. Rajput, an external expert, engaged in supporting the review process.

**Er. A. B. Pandya**
Secretary General, ICID

# ORGANIZING COMMITTEE

## Steering Committee (SC)

1. Minister of Public Works and Housing
2. Director General of Water Resources, Ministry of Public Works and Housing
3. President, Indonesian National Committee of ICID (INACID)
4. Director General of Water Resources and Irrigation, Ministry of National Development Planning Director General of Agricultural Infrastructure and Facilities, Ministry of Agriculture
5. Deputy for Coordinating the Acceleration of Infrastructure and Regional Development, Coordinating Ministry For Economics
6. Director General of Multilateral, Ministry of Foreign Affairs
7. Deputy for Marketing, Ministry of Tourism Governor of Bali

## International Steering Committee (ISC)

(i) Eng. Felix B. Reinders, President, ICID (Co-Chair)
(ii) Ir. Adang Saf Ahmad, President, INACID (Co-Chair)
(iii) Prof. Dr. Gao Zhanyi, President Hon., ICID & Chair ITAC
(iv) Mr. M. Zainal Fatah, Chairman, WIF3 (INACID)
(v) Er. Ashwin B Pandya, Secretary General, ICID (Member Secretary)

## International Technical Advisory Committee (ITAC)

**Members:** (i) PH Dr. Gao Zhanyi, Chair (ICID); (ii) VPH Dr. Ding Kunlun, Chair PCTA (ICID); (iii) VP Dr. Brian T. Wahlin, Chair, PCSO (ICID); (iv) VP Dr. K. Yella Reddy (ICID); (v) Mr. Momir Vranes, Chair, Australian NC (IACID); (vi) Dr. Olcay Unver (FAO); (vii) Mr. Jelle Beekma (ADB) (viii) Mr. Mawira Chitima (IFAD); (ix) Mr. Dale Jacobson (WWC); (x) Dr. Peter Carberry (ICRISAT); (xi) Ms. Julienne Roux (GWP); (xii) Mr. Ian Makin (IWMI); (xiii) Dr. Mukand S. Babel (AIT); (xiv) Mr. Syaiful Mahdi (INACID); (xv) Mr. Muhammad Amron (INACID); (xvi) Mr. Tunggul Imam Panudju (INACID); (xvii) Mr. Eko Subekti (INACID); (xviii) Mr. Abdul Malik Sadat Idris (INACID); (xix) Mr. Muradi (INACID) and (xx) Er. Ashwin B. Pandya, Secretary General, ICID.

## Organizing Committee (OC)

| | |
|---|---|
| **Chairman** | M.Z. Fatah |
| **Vice Chairman** | M. Arsyadi, Abdul Malik Sadat Idris, Agung Djuhartono |
| **Secretary** | Mochammad Mazid, Mohammad Irfan Saleh, Suroto |
| **Treasurer** | Trisasongko Widianto, John Pantouw, Nita Yuliati |
| **General Reporters** | Dr. Mochamad Amron, Prof. Nadjadji Anwar, Doddi Yudianto PhD., Dr. Willem Putuhena, Prof. Sri Harto, Prof Suripin, Dr. Robert Kodoatie, Dr. Barbara Katlyn, M. Adrie Azhari, Prof. Iwan Kridasantausa, Feriyanto Pawenrussi, Prof. Slamet Imam Wahyudi, Prof. Sigit Supadmo, Dr. Erigas Eka |

| | |
|---|---|
| **Panel of Experts** | Prof. RW Triweko, Prof. Indratmo Soekarno, Prof. Budi Santoso, Wignyosukarto, Dr. Moh. Hasan, Dr. Indreswari Guritno, Andi Sudirman, Dr. Ni Made Sumiarsih, Prof. Lily Montarcih, Dr. Abi Prabowo, Dr. Ismail Widadi, Juari, Dr. Momon Sodik Imanudin, Dr. Sriyana |
| **IEC Meeting** | Iwan Nursirwan, Syaiful Mahdi, Adek Rizaldi, Abdul Muis, Budi M. Habibie, Dyah Perdhani, Mohammad Ramdani |
| **WIF** | Mudjiadi, Widiarto, Yudha Mediawan, Theresia Sri Sidharti, Soekrasno, Rizal Siregar, Muradi, Marasi Deon Joubert , Haeruddin C. Maddi |
| **Fund Raising Division** | Jarot Widyoko, Wahyu Hadi Prasetyo, Gunawan Lukito, Moh Meizer, Mahading |
| **Exhibition** | Ruhban Ruzziyatno, Bobby Prabowo, Muhammad Asdin Thalib, Made Denny Satya Wijaya, Yus Yuni Sugiharto, Ardhita Agus Setiawan |
| **Promotion** | Mirza Nirwansyah, Kety Fillaily, Erystra Tiara, Krisno Yuwono, Gustav Sugiantoro. |
| **Tour Division** | T. Iskandar, IGN Diwangkara, , Sura Adnyana, Hendra Kurniawan, Andri Rachmanto |
| **Protocol and Function** | Airlangga Mardjono, Vena Rahayu Surya Saputra, Dedy Natrifahrizal Dedisky, Arif Ambar Prastiyo, Tesar Hidayat Musouwir, Yosiandi Radi Wicaksana, Alfa Tampubolon, Rudi Novianto Ridwan |
| **Registration, Accommodation, Venue, Logistic and Seminar Facility** | |
| | Eko Subekti, I Gusti Putu Wandira, Frida Koerdiati, Julianto Silalahi, Maria Christina Kurniawati, Darwanto, Muhamat Marasabessy. |
| **Cultural and technical tour, Social Program and Accompanying Persons Program** | |
| | I.G.N. Diwangkara, Sura Adyana, Andri Rachmanto, Tjok Bagus Purnawarman |
| **Transportation Division** | I Made Wirawan, Hendra Kurniawan, Mahalina Perwitasari |
| **Secretariat** | Andi Wildaniah, Sigit Marwanto, Rendhy Prasetyo, Gianoora Achmad, Sri Setiyawati, Endang Pribadi, Herlina Ayu Savitri, Sekar Adjeng Bramesti |

Page No.

## Sub-theme 1. Enabling Policy Environment for Water, Food and Energy Security

### Topic 1.1 Sustainable water Resources management policy; integration of surface water and groundwater to ensure water sustainability for environment and ecosystem, to support water, food, and energy security.

**Topic 1.2 Sustainable development of small and large scale irrigation system, lowland development and management for food security policy within the framework of global climate change, land consolidation management, and land conversion protection**

## Sub-theme 2. Role of Civil Society and Non-State Actors with Focus on Farmers and Extension Facilities

### Topic 2.1 Performance of public irrigation extension services in strengthening the irrigation management institutions



### Topic 2.2 The potential roles of non-government organizations, including private sector (NGOs) and civil societies in irrigated agriculture extension and advisory services including improvement of farmers livelihood (i.e. agricultural input, post-harvest technology, market chain, agro-based industry)

# WATER TABLE VARIABILITY AND FLOW RESPONSE OF TROPICAL PEATLAND - A CASE STDY

Nilna Amal[1], Joko Sujono[2] and Rachmad Jayadi[3]

**ABSTRACT**

Peatland is a type of soil that characterized by high water content. The use of peatlands, especially for agriculture and plantations is carried out by channel to control the water table level such that the water content in the root zone is in accordance by the variety of plant. Water table on drained peatlands will have a decline in groundwater level to a certain depth. Excessive continuous water table decreasing through below the surface of the land which occurs continuously can create irreversible dryness that causes land subsidence and increase the risk of fire (NOT CLEAR). The study aims to observe characteristics of water table level in the rainy season due to the construction of canal networks on peatlands.

The study was conducted in Pulau Padang Riau Province of Indonesia which is a drained peatland that has been developed for industrial crop cultivation. The land is managed by two different groups; those maintained by the local community and those by private companies. The analysis was carried out by using a balance of water budget on peatland specifically by calculating the dynamic interaction of the hydrological parameters of land and channels flow.

The results showed that the condition of water table elevation had changed during the period of data collection. The rainfall transformed quickly into overland flow and direct runoff. The decrease in the water table on local community management areas is higher than that occurring in companies land with a variety in the value of the up and down is greater.(NOT CLEAR) This phenomenon occurs because there are no canal blocks on the peatland, which is managed by the local community so that the rise and fall of the water surface occur naturally. In addition, since it is located in the downstream area, the state of the flow will be influenced by the flow in the upstream. When the upstream flow is retained, hence no current flows to the downstream, and as a result, the water table level continues to decrease.

**Keywords :** peatlands, water table depth, rainfall, direct runoff.

## 1. INTRODUCTION

Deforestation, especially peat forests, has received attention from researchers. Some of the research articles cover the forest point of views such as the quantity area of forest loss, the amount of carbon decomposed into the atmosphere and the reduced number of specific plants. Others present hydrology altering characteristics widely and consistently such as changes in hydraulic conductivity and changes in the type of peat layer (Curran et al., 1999; Curran et al., 2004; Wöstenet al.,2013). The significant role of peatlands including swamp, for instance, the ability to store carbon stocks, as a source of water and even as an alternative to decreasing floods (Holden, 2005; Acreman and Holden, 2013), trigger it to be an essential research object. The

[1] Ph.D student at Dept Civil and Environmental Engineering, Universitas Gadjah Mada; Email : nilna.amal@mailugm.ac.id

[2] Department Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada; Email: jsujono@ugm.ac.id

[3] Department Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada; Email: rjayadi@ugm.ac.id

proper analysis of how to manage peat soil is needed to provide benefits that are greater than the losses incurred due to the converting function.

Management of peatlands requires channel to achieve a water table level that is appropriate for plants. According to its characteristics, the flooded or watery swamp area with peat soil requires special handling before it is used as plantation or agricultural land, which is carried out canalization. Peatlands need channels to prepare them so that those have a water content that is following the types of plants to be planted (Mitsch and Gosselink, 2015). Water channelization of peatlands causes various effects such as, altering the composition of the acrotelm-catotelm in the top layer, changes in groundwater level, , changing the fluctuation of overflow and carbon reduction (Grand-Clement, et al., 2015; Daniels, et al., 2008, Holden et al., 2006, Holden, 2005).

Tropical Peatlands in Indonesia has been a concern and subject of research for a long time. Peatlands are distributed in Sumatra Island, Kalimantan Island and, a little in Papua Island. Sumatra peatlands as in Kalimantan include high in depth, and some have undergone drainage, but the level of research is not as much as research on Kalimantan peatlands (NOT CLEAR) (Page et al., 2002). One of them is research on the Pulau Padang (Brady, 1997). Some of them are intended to provide recommendations for other tropical countries that have not yet converted much of their peatlands, such as Peru and the Republic of Congo (Murdiyarso et al., 2019). Others are to see what influence is dominant in Kalimantan forest loss (Curran et al., 2004) or the amount of carbon released by peatlands in the fires that occurred during 1997 (Page et al., 2002).

Research on peatland areas in the tropics such as Indonesia has differences with the other four season countries, such as very thick peat depths of up to more than 12 meters like those on the Pulau Padang Riau Province (Brady, 1997). Pulau Padang is a deep peatland (peat depth of more than 3 meters) that has been converted into a variety of plantations (Karyanto, 2000). Detailed local research is needed in certain peat areas to understand how a land transformation and their use cause changes in ecological interactions (Curran et al., 2000) especially on land that has experienced canalization such as Pulau Padang. As a peat area that has been canalized, has felt need for research to see the changes in hydrological characteristics with the presence of canals and for using the peatlands for plantations. The study aims: 1) to compare the state of the water table elevation on peatland that are managed by the community and maintained by the company, 2) to analyze the state of the groundwater fluctuations and 3) to describe the process of runoff in channelled peatlands during rainfall.

## 2. METHODS

### 2.1 Location of study: Pulau Padang district Riau Province

The study was conducted on one of the drained tropical peatlands in Riau Province and carried out for two months, from November to December 2017 and arranged it at two location points representing community-managed land and the company's concession area.The more explanations are in the description below.

Pulau Padang is one of a series of four main islands within the Meranti Islands Regency, Riau Province, which consists of two sub-districts, namely Merbau District and Tasik Putri Puyu District. Pulau Padang is a Peatland Hydrological Unity( Kesatuan Hidrologi Gambut KHG) with entirely area is 1.114,04 km$^2$. Geographiccally Kepulauan Meranti discrict is located 0° 42' 30"- 1° 28' 0" N dan 102° 12' 0"- 103° 10' 0" E. The climate in Pulau Padang as well as in the Kepulauan Meranti district region is temperate with maximum air temperatures ranging from 25°C – 32°C (BPS Kepulauan Meranti District, 2017). Figure 1 below shows the area of the study

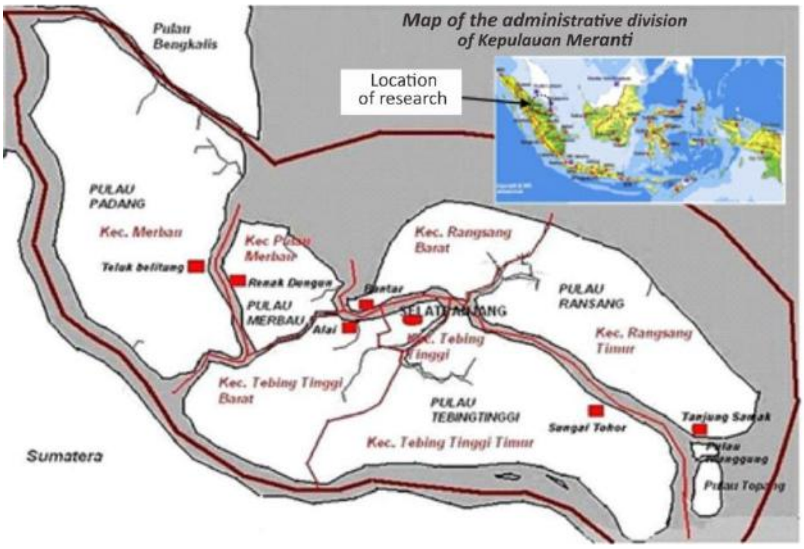


**Figure 1**. Location of research

Pulau Padang has a flat topography with a maximum height of 15 m above mean sea level (MSL). The Thickness of peat on Pulau Padang, like others in Indonesia peatland such as Kalimantan tends to be more than 3 meters. The primary type on Pulau Padang is 6 meters or more in depth so that it can be categorized as deep peat, depth of groundwater tends to be more stable than shallow peat (Brady, 1997).

### 2.2 Characteristic soil and the community

Pulau Padang Island is one of the peat islands that has been inhabited by the people since the late 19th century and has been the object of research on peat age and the organic dynamics of peat soil for so long. Peat is defined in two ways, namely through its chemical conditions and its hydrological state. Based on its chemical state peat is divided into 1) minerotropic (true fens), 2) ombrotropic (raised bogs) and 3) transition (poor fens). The classification is based on a hydrological state that is 1) geogenous (according to the flow from the outside) and (2) ombrogenous (the flow originating only from rain). Ombrotropic or ombrogenous peat is isolated from mineral groundwater with a pH and low mineral content. Acidity in peat is affected by changes in cations with moss, oxidation of sulfur compounds and organic acids (Mitsch and Gosselink, 2000).

Based on the thickness of the layer of organic matter, peat can be classified as follows (Noor, 2001) :

1. Thickness of peatland 50-100 cm called swallow dome
2. Thickness of peatland100-200 cm called middle dome
3. Thickness of peatland200-300 cm called deep dome
4. Thickness of peatland200-300 cm called high deep dome

On Pulau Padang peatland, there is a concession area managed by PT Riau Andalan Pulp and Paper (RAPP) which cultivates pulp plants for paper industry. In addition, cultivation practices are also carried out on land owned by local communities which are dominated by rubber, coconut and sago palm trees.

Of all the fields on Pulau Padang, 31% of them are conservation spaces. The area of 347.11 km$^2$ includes Tanjung Padang Wildlife Reserve /Suaka Margasatwa Tanjung Padang 48.57 km$^2$, PT GCN Pulau Padang licensed restoration range 204.37 km$^2$, and PT RAPP licensed permit area 94.17 km$^2$. Outside the region is under the management of local governments, most of which are used for local community activities as shown in Figure 2.


**Figure 2.** Mapping ofconservation zone by every concession on Pulau Padang.

## 2.3 Field Measurements

Hydrological data needed are rainfall data, flow data, and water table elevation (WTE) data. Data collected is daily rainfall measured using automatic rain gauge (ARR) for 10 minutes series. The two sets of equipment are installed in Sei Hiu, Tanjung Padang Village, and Bagan Melibur Village. In addition to the two types of data, other meteorological data are also obtained such as wind speed and air humidity that have been incorporated in the measuring instrument. Location and installation setting of the equipments in the sketch can be seen in Figure 3and Figure 4 below.

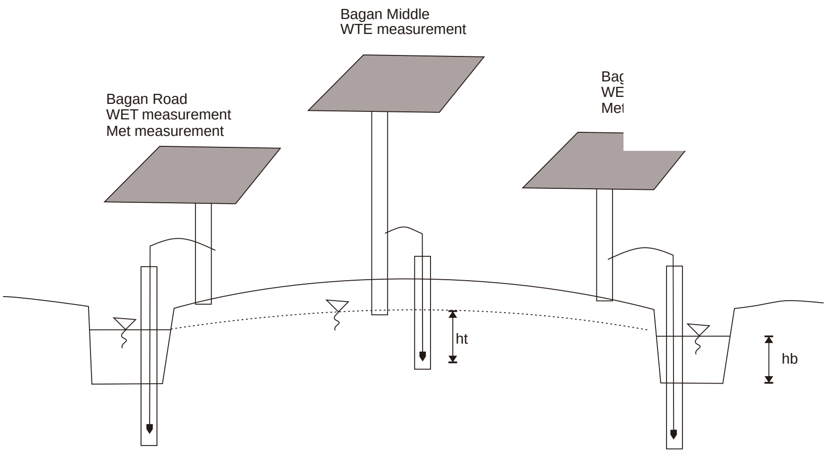


**Figure 3.** Sketch of the measurement


**Figure 4.** Location both of equipment setting

## 2.4. Review of Water Balance Equations on Peatlands and Discharge Analysis on the Channels

Water table elevation change data can be used to study the influence of the presence of channels and land cover on groundwater fluctuations. The water balance equation can analyze alteration in the groundwater level. The formulation will be different for drained peatlands with network systems with that are still intact. It happens because the presence of canals will significantly influence the groundwater fluctuations that are affected by the rate of groundwater wear by the process of subsurface runoff.

The general equation, based on the hydrometeorological cycle of water balance, is in a rainfall condition with the assumption that before the canal network is settled as follows.

$$\Delta S = \mathrm{P} - ET - RO - I$$

where:

*P* :rainfall (mm/day),
*ET* : evapotranspiration (mm/day),
*RO* :surface flow (mm/day),
*I* : infiltration (mm/day),
$\Delta S$ :water storage change (mm/day).

The discharge that occurs for each rainfall event is calculated as the description below. The total runoff volume leading to the canal (VRO) is equal to the above-ground runoff volume (SRO) coupled with the subsurface runoff volume (SSRO) and changes in groundwater storage can be stated as follows.

$$\Delta S = \sum I - \sum O$$
$$\Delta S = VP - (VRO + VET)$$

by:

$\Delta S$ :change in water storage volume ($m^3$),
$\sum I$ :total of*inflow* = volume of rainfall ($m^3$),
$\sum O$ :total of *outflow*= *runoff*+ evapotranspiration ($m^3$),
*VP* :rainfall in volume ($m^3$),
*VET* :evapotranspiration in volume ($m^3$),
*VRO* : volume of total direct runoff total flow to canal ($m^3$).

## 3. RESULTS AND DISCUSSION

Peatland management carried out by two large groups will distinguish the peat hydrological conditions that have been managed. It managed by the community have simple characteristics, have not implemented a regular system and have almost no canal blocking. On the other hand, the land runs by the company have higher network density characteristics and regularity of the channel system including the presence of canal blocking.

### 3.1 Analysis of changes in groundwater level

The analysis used rainfall data from automatic rain gauges and water table level data from automatic water level recorder. The following is a graph obtained from the two pieces of equipment. Analysis of water table level and presentation of events is shown in Figure 5 below. Water table elevation and presentation of certain heights is carried out with steps like the following.

1. Sort all the water level data (for example in Bagan Melibur the water level data ranged from -1.888 m to -0.303m.

2. Making a data interval, in this case, made from smaller than -1.888 m until the upper one, i.e., 0.3 m.

The data range determines the length of the period. In Sei Hiu because data range is only in the of -0.6 m to -0.4 m, the interval value also ranges from those of it.

1. Calculate the amount of data on each interval.

   Example: number smaller than -1.9 is 22 data from 5621 data and a range of 10 minutes.
2. Measure the percentage of each interval, for example for lower data (higher than particular interest).
   a. 1.8 = (22/5621x100%) = 0.39%.
   b. 1.7 = ((22+37)/5621x100%) = 1.05% and so forth.

Figure 5 below shows the condition of water table elevations at the two locations where data was taken during the study. The noticeable difference is the antecedent of the groundwater wherein Bagan Melibur reaches a depth of -1.9 m while the Sei Hiu is only -0.7 m. The differences between both of them it is possible due to the presence of canal block that makes Sei Hiu only loss a little part of the water in the dry season compared to Bagan Melibur.

The graph in the figure 5. below shows that there are differences in the trend of changes in the water table level in the two areas. Bagan Melibur tends to have a high level of variability, namely the water table level from -0.6 m to -1.9 m while it in Sei Hiu only ranges between -0.4 m to -0.6 m. Compared to government regulations regarding the maximum allowable depth for peatlands to be damaged, i.e., 0.4m, it can be concluded that Sei Hiu is still within safe limits while Bagan Melibur into hazardous areas even tends to be risky because at the beginning of the wet season it reaches up to -1.9m.

In the Bagan Melibur area, it can be seen that the water table level below 40 cm takes place less than 10%, which means that nearly 90% of the depth of the water table that happens is not at the recommended level. In the Sei Hiu area, the water table level lower than 40 cm occurs more than 70% so that the water depth limit that exceeds the allowable limit only occurs at a maximum of 30%.

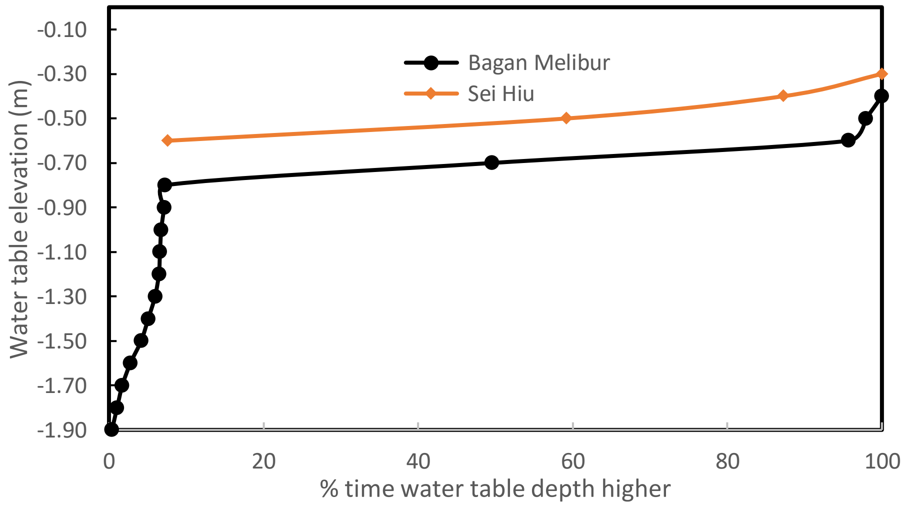


**Figure 5.** Water table frequency curves for Bagan Melibur dan Sei Hiu

Some of the differences between the two zones that can be mentioned as the causes of these facts are Bagan Melibur, which is a community managed area that does not yet have canal blocks. It means it does not have a scheme that can be used to hold water so that rainwater flowing as runoff directly flows to downstream and does not have time to influence the water table level change on the land. While Sei Hiu area which is located upstream has a canal block so that it has the opportunity to hold water for longer on the preferred channel section so that if the land started has begun to dry, the water is not allowed to flow downstream.This situation makes alterations in the water table level in Sei Hiu tend to be better than Bagan Melbur area. The presence of canal blocks in research on Central Kalimantan peatlands (Ritzema et al., 2014) has raised the water level significantly to elevations above -0.4 m after previously reaching below -1.22 m but unable to maintain the water level in the dry season. The trend of lower water level in the downstream area also occurred in this study.

There is a positive correlation between changes in water table level, and the presence of channels (Luscombe et al., 2016; Page et al., 2009) that is artificial drainage decreases the extent of the water table. In this study, both locations have a human-made channel, and the depth of the groundwater varies, but those are strongly influenced by the occurrence of rain which is consistent with research on peatlands in Kalimantan (Ritzema et al., 2014).

The hydrological response to the previous low groundwater conditions (antecedent) shows that the discharge rises rapidly while the groundwater level tends to be flat and even static (Daniels, et al., 2008). In the rainfall event November6th 2017, the antecedent height of water table level at Bagan Melibur and Sei Hiu are -1.9 m and -0.6 m respectively. In this study, the Pulau Padang state, when rainfall fell in Bagan Melibur then water table level rose rapidly to a height of -0.8 m with antecedent height was -1.9, then it took a long time to rise to an elevation of 0.7m. When the rain prolonged the water table only rose gently until it reached a stable state at 0, 4 m so that the situation was different from Daniels' 2008 study in South Pennines, UK.

### 3.4 Analysis of alteration in water table level and discharge generated

Drainage has a considerable influence on flow generation and groundwater spatial based (Holden et al., 2006) so that on a drained peatland like Padang Padang, it is necessary to do a spatial based flow analysis. Those are laid on different topography, i.e., Sei Hiu located upstream, and Bagan Melibur positioned in the downstream area. Some rain has occurred during the period of data collection, as follows in Figure 6 present the relationship between rain events with the generated discharge flow.

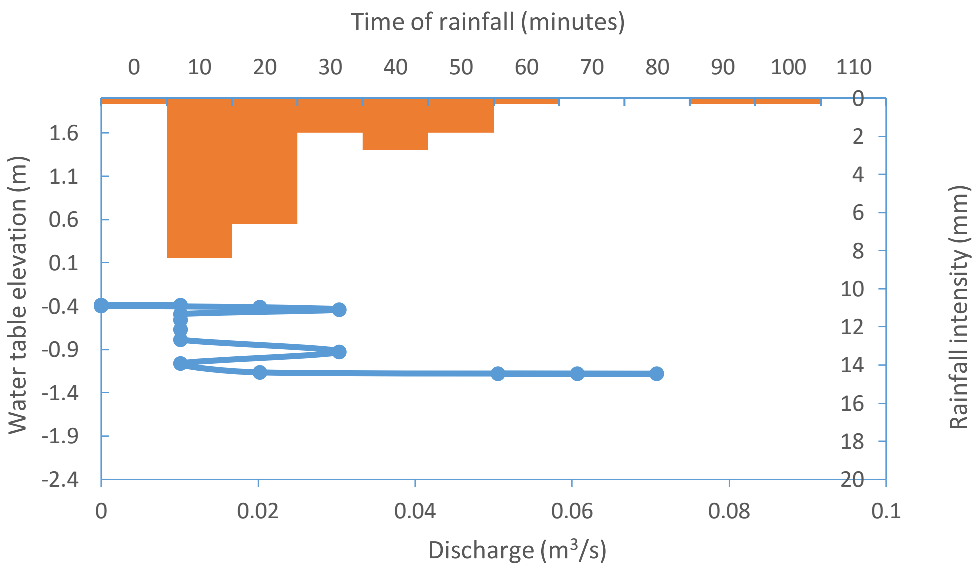


**Figure 6.** Profile of rainfall and discharge vs water table elevation onNovember 6th2017.

It can be seen in this study that discharges do rise rapidly (Figure 6), in contrast to Daniels et al, 2008, the ground water level rises slowly or even tends to be static. On the other hand, it is rising rapidly as seen in the November 6th rain event. In this event the groundwater level was initially at position -1.2 m and in the first 10 minutes with a rainfall height of 6.3 mm, there is a discharge of 0.06 $m^3$/s and the water table level is still in the number -1.2; then one hour later the groundwater level has become -0.8 with a total rainfall of 36.3 mm. The increase in water table level continues even though the rain begins to decrease and one hour later the water table level has reached 0.4 and after that the ground water level is relatively constant. The difference in response to hydrological conditions in an area is mainly determined by the heterogeneity of the region spatially and temporally and is included in the peculiarities of each peatland. It is possible due to the state of the composition of peat and differentiation of the depth layer of peat alongside the presence of canal blocking. Since there are difference between these both composition peatlands it will be needed a comprehensive study like the depth of peatland and the conductivity hydraulics.

## 4. CONCLUSIONS

Research on the location of Pulau Padang peatlands shows that there are significant changes in groundwater levels during the period of data collection, namely November to December 2017. Changes in water level are mainly determined by the incidence of rainfall and the condition of the initial water level at an elevation that exceeds the regulation recommended by the government, which is -0.4m. There are similarities and differences in the two locations of study. The hydrological response in the two regions, especially the flow rate in the channel looks the same only in the Sei Hiu there is no previous condition (antecedent) with an insignificant water table level. Further research is needed on the state of change in the dry season where the evaporation takes place and has a principal influence on the influence of thick peat on changes in land surface and flow response.

## REFERENCES

Acreman M., and J. Holden, 2913, How wetlands affect floods, Wetlands, 33: 773-786.

Astiani, D, L. M. Curran, Burhanuddin, M. Taherzadeh, Mujiman, M. Hatta, W. Pamungkas, E. Gusmayanti, 2018, Fire-Driven biomass and peat carbon losses and post-fire soil CO2 emission in a West Kalimantan peatland forest.

Brady, M. A., Organic matter dynamics of coastal peat deposits in Sumatra, Indonesia, a dissertation thesis, University of British Columbia, Canada.

Curran, L. M., I. Caniago, G. D. Paoli, D. Astiani, M. Kusneti, M. Leighton, C. E. Nirarita, H. Haeruman, 1999, Impact of El Nino and logging on canopy tree recruitment in Borneo, *Science* 286: 2184-2188.

Curran, L. M., N. Trigg, A. K. McDonald, D. Astiani, Y. M. Hardiono, P. Siregar, I. Caniago, E. Kasischke, 2004, Lowland forest loss in protected areas of Indonesian Borneo, *Science* 303: 1000-1003.

Daniels, S.M., C. T. Agnew, T. E. H. Allot, M. G. Evans, 2008, Water table variability and runoff generation in an eroded peatland, South Penines, UK, *Journal of Hydrology*, 361:214-226.

Grand-Clement, E., K. Anderson, D. Smith, M. Angus, D. J. Luscombe, N. Gatis, L. S. Bray, R. E. Brazier, 2015, Review

Holden, J., and T. P. Burt, 2003, Hydrological studies on blanket peat: the significance of the acrotelm-catotelm model, *Journal of Ecology*, 91: 86-102.

Holden, J., 2005, Peatland hydrology and carbon releas: why small-scale process matters, *Phil-Trans R Soc, Math, Phys and Eng Sci*ence 363: 2891-2913.

Luscombe, D. J., K. Anderson, E. Grand-Clement, N. Gatis, J Ashe, P Benaud, D. Smith, R. E. Brazier, 2016, How does drainage alter the hydrology of shallow degraded peatlands across multiple spatial scales?, *Journal of hydrology*, 541: 1329-1339.

Mitsch, W.J., J.G. Gosselink, 2015, Wetlands, fifth edition, John Wiley & Son, United State of America.

Murdiyarso, D., E. Lilleskov, R. Kolka, 2019, Tropical peatlands under siegeaaa; the need for evidence-based policies and strategies, *Mitigation and Adaptation Strategies for Global Change*, 24: 493-505.

Noor, M., 2001, *Pertanian lahan gambut, potensi dan kendala*, Penerbit Kanisius, Yogyakarta.

Page, S.E., F. Siegart, J. O. Rieleys, H. V.,Boehm, A. Jaya, S. Limin, 2002, The amount of carbon released from peat and forest fires in Indonesia during 1997, *Nature* 420:61-65.

Page, S., A. Hoscilo, H. Wösten, J. Jauhiainen, M. Silvius, J. Rieley, H. Ritzema, K. Tansey, L. Graham, H. Vasander, S. Limin, 2009, Restoration ecology of lowland tropical peatlands in Southeast Asia: current knowledge and future research directions, *Ecosystems*, 12: 888-905.

Ritzema, H., S. Limin, K. Kusin, J. Jauhiainen, H. Wösten, 2014, Canal blocking strategies for hydrological restoration of degraded tropical peatlands in Central Kalimantan, Indonesia, *Catena*, 114: 11-20.

Wosten, J. H. M., E. Clymans, S. E. Page, J. O. Rieley, S. H. Limin, 2008, Peat-water interrelationships in a tropical peatland ecosystem in Southeast Asia, *Catena*, 73: