



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



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**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:



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International Commission on Irrigation and Drainage (ICID)



INACID



Hosted by:

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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.

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CONTENTS

	Page No.
1. Welcome	(v)
2. Foreword	(vii)
2. Preface	(ix)
3. Organizing Committee	(xi)
4. World Irrigation Forum: A Platform for Stakeholders	(xiii)
5. 3 rd World Irrigation Forum: Development for Water, Food and Nutrition Security in a Competitive Environment	(xv)
6. Background Papers	1
Sub-Themes 1. Enabling Policy Environment for Water, Food and Energy Security	3
Sub-Themes 2. Role of Civil Society and Non-State actors with Focus on Farmers and Extension Facilities	31
Sub-Themes 3. Improving Agricultural Water Productivity with Focus on Rural Transformation	49
7. Index of papers	63
8. Background Paper Contributors	287
9. International Review Committee	293
10. Author Index	297

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, to face some serious challenges in the 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 the 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 a 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

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Index of papers

	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.	
W.1.1.01 MICRO IRRIGATION INFRASTRUCTURE ON CANAL COMMANDS FOR SUSTAINABLE RICE AND WATER PRODUCTIVITY UNDER DECLINING WATER AVAILABILITY IN NORTH-WESTERN PLAINS OF INDIA Neeraj Sharma, Rakesh Chauhan, A K Bhardwaj, and T. Pandiaraj	83
W.1.1.02 EFFECTS OF IRRIGATION WATER SALINITY ON SOIL N ₂ O EMISSION AND YIELD OF SPRING MAIZE UNDER MULCHED DRIP IRRIGATION Chenchen Wei, Peiling Yang, Shumei Ren, Shuaijie Wang, Yu Wang, and Ziang Xu	84
W.1.1.03 SUSTAINABLE MANAGEMENT OF WATER IN NORTHERN CALIFORNIA, USA, FOR FOOD, ENERGY, AND ENVIRONMENTAL SECURITY W. Martin Roche	85
W.1.1.04 NITROGEN AND PHOSPHORUS LOSS CHARACTERISTICS UNDER AN IMPROVED SUBSURFACE DRAINAGE YuanTao, Shaoli Wang, Xiaoyan Guan, Di Xu, and Haorui Chen	86
W.1.1.05 MULTIFRACTAL CHARACTERISTICS OF SOIL PARTICLE SIZE DISTRIBUTION UNDER SEWAGE IRRIGATION IN DIFFERENT IRRIGATION YEARS Guan Xiao-Yan, and LV Ye	87
W.1.1.06 OPTIMAL IRRIGATION PLANNING AND OPERATION OF RESERVOIR USING SELF-ADAPTIVE CUCKOO SEARCH ALGORITHM (SACSA) Sriman Pankaj Boindala, and Vasan Arunachalam	88
W.1.1.07 ENERGY PRODUCTIVITY OF INDIAN AGRICULTURE: ARE ENERGY GUZZLING DISTRICTS GENERATING HIGHER AGRICULTURAL VALUE? Abhishek Rajan and Kuhelika Ghosh	89
W.1.1.08 RECKONING THE GROUND WATER RECHARGE IN SEMI-ARID REGION: AN ASSESSMENT OF COMMUNITY LED POLICY PERFORMANCE IN SAURASHTRA Prahars Patel and Dipankar Saha	90
W.1.1.09 A MODEL TO INTEGRATE AND ASSESS WATER-ENERGY-FOOD NEXUS PERFORMANCE: SOUTH AFRICA CASE STUDY Luxon Nhamo, Tafadzwanashe Mabhaudhi, and Sylvester Mpandeli	91
W.1.1.10 ANALYSIS OF IRRIGATION WATER EFFICIENCY IN GUANGDONG PROVINCE BASED ON STOCHASTIC FRONTIER ANALYSIS (SFA) Kang ZHANG, Zhipeng MA, Qunfang FAN, and Jiangli ZHENG	92

W.1.1.11	GRAVITY DRAINAGE FOR CROPPING INTENSIFICATION IN POLDERS OF THE COASTAL ZONE OF BANGLADESH Manoranjan K. Mondal, Sudhir-Yadav, Elizabeth Humphreys, S V Krishna Jagadish, Zahirul H. Khan, Asish Sutradhar, and Farhana A. Kamal	93
W.1.1.12	ASSESSING AGRICULTURAL RESERVOIRS AS THE SOURCES OF ENVIRONMENTAL FLOW: CASE STUDY IN KOREA Kwang -Sik Yoon, Young-Jun Jo, Seung-Hwan Yoo, and Younggu Her	94
W.1.1.13	GROUNDWATER QUALITY CONCERNS STILL EXIST IN HIGH WATER PRODUCTIVITY AREAS Chittaranjan Ray, Crystal A. Powers, and Mesfin M Mekonnen	95
W.1.1.14	WATER ENERGY FOOD NEXUS IN PRACTICE: EXAMPLES FROM SOUTH ASIA S.A. Prathapar, A. Cauchois, and L. George	96
W.1.1.15	VULNERABILITY ASSESSMENT OF AGRICULTURAL RESERVOIR WATER SUPPLY CAPACITY Jehong Bang, and Jin-Yong Choi	97
W.1.1.16	ISSUES RELATED TO CONFIRMATION OF RIGHT FOR IRRIGATION WATER TO FARMERS IN CHINA Changshun LIU, and Lijuan DU	98
W.1.1.17	INTEGRATION OF GROUNDWATER RESOURCES IN WATER MANAGEMENT FOR BETTER SUSTAINABILITY OF THE OASIS ECOSYSTEMS - CASE STUDY OF TAFILALET PLAIN, MOROCCO El Khoumsi Wafae, Ali Hammani, Marcel Kuper, and Ahmed Bouaziz	99
W.1.1.18	MALAYSIA'S NATIONAL WATER BALANCE MANAGEMENT SYSTEM: MANAGEMENT OF WATER RESOURCES AND IRRIGATION DEMAND WITH WATER RESOURCES INDEX (WRI) N. Mohd Ghazali, M.W. Husain, A. M. Ishak, N. Redzuan and F.H. Lim	100
W.1.1.19	REVALUATION OF LOCAL KNOWLEDGE AS A SUSTAINABLE DROUGHT ADAPTATION STRATEGY Muhamad Khoiru Zaki, Keigo Noda, Kengo ITO, and Komariah	101
W.1.1.20	ALLOCATION OF WATER-LAND-ECOLOGY-ECONOMY FOR SUSTAINABLE RICE DEVELOPMENT IN SJP OF CHINA Longzhu Guo, and Fengqing Liu	102
W.1.1.21	PROJECTING AGRICULTURAL WATER SUPPLY RELIABILITY UNDER DIFFERENT ET APPROACHES AND CLIMATE CHANGE Cho Gun-Ho, Kim Sang-Hyun, Mirza Junaid-Ahmad, Han Kyung-Hwa, and Choi Kyung-Sook	103
W.1.1.22	DEVELOPMENT OF QUANTITATIVE ASSESSMENT FOR INTEGRATED IRRIGATION-AGRICULTURE Sahid Susanto and Nurul Pertiwi	104
W.1.1.23	ANALYSIS OF CORRELATION WITH ENERGY CONSUMPTION IN SUPPLYING WATER FROM RESERVOIRS TO RICE PADDY FIELDS Eunhee Choi, Seungheon Lee and Seungoh Hur	105
W.1.1.24	MODERNIZATION AND USERS PARTICIPATION, A KEY ISSUE TOWARDS IRRIGATION SUSTAINABILITY IN VALDICHIANA, CENTRAL ITALY Graziano Ghinassi and Lorella Marzilli	106

W.1.1.25	WASTEWATER AND GROUNDWATER CONJUNCTIVE USE OPTIMIZATION MODEL IN VARAMIN IRRIGATION NETWORK Maryam Yousefi, Mohammad Ebrahim Banihabib, and Jaber Soltani	107
W.1.1.26	ASSESSMENT OF REGIONAL DIFFERENCES IN SUSTAINABILITY OF RURAL RESOURCES BY NEXUS-BASED ANALYSIS Yoonhee Lee, Jin-Yong Choi, Pureun Yoon, Kwihoon Kim and Sang-hyun Lee	108
W.1.1.27	EVALUATION OF WATER-ENERGY-FOOD LINKAGES BASED ON THE GREENHOUSE TEMPERATURE MODEL AND ANN Kwihoon Kim, Pureun Yoon Nahun, Yoonhee Lee, Sang-Hyun Lee and Jin-Yong Choi	109
W.1.1.28	DETERMINATION OF DEPENDABLE FLOW FOR MICROHYDRO POWER PLANT IN IRRIGATION NETWORK Afida Zukhrufiyati, Joko Triyono, Segel Ginting, and Eko Winar Irianto	110
W.1.1.29	AN IRRIGATION STRATEGY TO EXTERMINATE APPLE SNAILS (POMACEA CANALICULATA) EGGS IN TAIWAN PADDY FIELDS Yu-Chuan Chang, Kunihiko Yoshino, Ching-Tien Chen and Gwo-Fong Lin	111
W.1.1.30	SUSTAINABLE RAINWATER RESOURCES MANAGEMENT POLICY TO SUPPORT WATER, FOOD AND ENERGY SECURITY Susilawati Cicilia Laurentia, Kristono Yohanes Fowo, and Charly Mutiara	112
W.1.1.31	RAINWATER HARVESTING IN THE 21ST CENTURY – AN AUSTRALIAN PERSPECTIVE Michael Smit	113
W.1.1.32	SIMPLE TOOL FOR ANALYZING CANAL SYSTEMS IN MIXED URBAN AND RURAL ENVIRONMENTS Brian Wahlin, Bert Clemmens, Brent Travis and Jorge Garcia	114
W.1.1.33	MANAGING COMPLEXITY FOR SUSTAINABILITY. EXPERIENCE FROM GOVERNANCE OF WATER-FOOD-ENERGY NEXUS Dubravka Bojic, and Domitille Vallée	115
W.1.1.34	POLICY FRAMEWORK FOR IMPLEMENTING FOOD-WATER-ENERGY NEXUS IN AGRICULTURE IN SOUTH ASIA Golam Rasul, Nilhari Neupane, and Jelle Beekma	116
W.1.1.35	GREEN AND BLUE WATER REQUIREMENTS FOR SUSTAINABLE PAKISTAN'S STAPLE CROP PRODUCTION UNDER FUTURE CLIMATE CONDITIONS Mirza Junaid Ahmad, Gun-Ho Cho, Seulgi Lee ¹ and Kyung-Sook Choi	117
W.1.1.36	IDENTIFICATION OF FACTORS AFFECTING WATER QUALITY AND POLLUTANT OF SEDIMENT IN AGRICULTURAL RESERVOIRS Sang-Yun You, Ju-Tai Song, Suk-Goun Youn, Jae-Woon Jung, Jae-Chun Lee, Jae-Young Lee, Dae-Hoon Kim, and Kwang-Sik Yoon	118
W.1.1.37	URBAN DRAINAGE SYSTEM, URBAN AGRICULTURE AND SWAMP RETENTION DEVELOPMENT IN PALEMBANG CITY F.X. Suryadi, Akhmad Bastari Yusak, W.A. Marlina Sylvia, Eka Gustini, and Mohd Sharizal Ab Razak	119

W.1.1.38	CAUSAL LOOP DIAGRAM OF WEF SECURITY NEXUS: AN IMPLEMENTATION OF GROUP MODEL BUILDING Aries Purwanto, Janez Sušnik, F.X. Suryadi, and Charlotte de Fraiture	120
W.1.1.39	RECENT ADVANCES IN SALINITY MANAGEMENT IN AGRICULTURE: INDIAN EXPERIENCE Gurbachan Singh	121
W.1.1.40	SUSTAINABILITY OF WATER RESOURCES MANAGEMENT POLICY: TIME FOR A PARADIGM SHIFT FOR ENSURING FUTURE FOOD SECURITY AND WATER RESOURCES Bashir adelodun, Seul Gi Lee, and Kyung Sook Choi	122
W.1.1.41	THE PRELIMINARY STUDY ON ENHANCEMENT STRATEGY FOR WATER QUALITY MANAGEMENT IN XILUO IRRIGATION AREA OF TAIWAN Ke-Chun Lin, Ying-Chun Lin, Ching-Ru Tang, Chong-Yuan Lin and Pi-Hui Suzi Chang	123
W.1.1.42	DEVELOPING POROUS STRUCTURES TO IMPROVE WATER QUALITY ON TIDAL LOWLAND AGRICULTURE OF SOUTH SUMATERA INDONESIA Momon Sodik Imanudin, Bakri and Birendrajana	124
W.1.1.43	THE WESTERN CONJUNCTIVE MANAGEMENT FALLACY: GROUNDWATER IN THE WESTERN UNITED STATES Sarah Liljefelt and Therese Ure	125
W.1.1.44	DEVELOPING NATIONAL DESIGN STANDARD FOR IRRIGATION AND DRAINAGE TO SUPPORT WATER AND FOOD SECURITY IN CAMBODIA Ketya Hun, Sytharith Pen, Pinnara Ket, Bin Dong, Garry Ellem and Sarann Ly	126
W.1.1.45	RAINFALL DISTRIBUTION ANALYSIS TO ASSIST CROP SELECTION AND IRRIGATION PLANNING J. Niharika, K.Yella Reddy, L. Narayana Reddy, and K.V.Jayakumar	127
W.1.1.46	A HOLISTIC WATER MANAGEMENT FOR WATER-FOOD NEXUS SECURITY: THE CASE OF EGYPT Amin Elshorbagy ,and Ahmed Abdelkader	128
W.1.1.47	EFFICIENT AND PRODUCTIVE WATER USE FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN INDIA S Masood Husain, Navin Kumar and Chaitanya K S	129
W.1.1.48	WATER QUALITY CHARACTERISTICS TO THE WATER-ENERGY-FOOD (WEF) NEXUS Yuliya Mahdalena Hidayat and Dini Nur Utami	130
W.1.1.49	WATER SECTOR AS A SILENT GAMECHANGER: CASE STUDY OF INDIA Vivek P. Kapadia	131
W.1.1.50	APPLYING CIRCULAR ECONOMY ON POLLUTION REMEDIATION AND INTEGRATED MANAGEMENT IN DONGGANG RIVER BASIN, TAIWAN Lu, Tai-Ying, Ting, Cheh-Shyh	132
W.1.1.51	CLIMATE CHANGE IMPACT ON WATER AND POWER OPERATION IN URBANIZED AREA - A CASE STUDY OF TAOYUAN CITY, TAIWAN Kai-Yuan Ke and Yih-Chi Tan	133

W.1.1.52	PRO-POOR AGRICULTURAL POWER POLICY FOR WEST BENGAL Manisha Shah, Sujata Das Chowdhury, and Tushaar Shah	134
W.1.1.53	CHALAKUDY RIVER DIVERSION SCHEME, KERALA: DOES IT SHOW THE FUTURE OF CANAL IRRIGATION IN INDIA? Harikrishnan Santhosh, Amal Mohan and Sruthi Laura George	135
W.1.1.54	EVALUATION OF WATER DEMAND SUPPLY ON TISZA RIVER BASIN János Tamás, Bernadett Gálya, Erika Buday Bódi, Tamás Magyar, and Attila Nagy	136
W.1.1.55	FUTURE PRECIPITATION PROJECTIONS AND ITS POTENTIAL IMPACT FOR DEVELOPMENT AND MANAGEMENT OF IRRIGATION OVER INDONESIA Radyan Putra Pradana, and Widya Utaminingsih	137
W.1.1.56	CONJUNCTIVE EXPLOITATION OF SURFACE AND GROUNDWATER IN THE EASTERN OF NILE DELTA Eman W. Nofal, and Ahmed M. Aly	138
W.1.1.57	TRANSBOUNDARY RIVERS: WATER SAVING POLICY AND MUTUAL COMPENSATION FOR ENVIRONMENTAL DAMAGE Yury Mazhayskiy, Aliaksandr Volchak, Aleh Meshyk, Lubov Hertman, and Inna Davydova	139
W.1.1.58	THE STUDY ON ARTIFICIAL RECHARGE OF GROUNDWATER FOR LAND SUBSIDENCE USING EXISTING AGRICULTURAL PONDS Ting Cheh-Shyh, and Chuang Chi-Hung	140
W.1.1.59	WATER CONSERVATION STRATEGIES FOR BEIJING CAPITAL REGION, CHINA Hubert Jenny, Mingyuan Fan, Yihong Wang, Paul Bulson, Liu Peibin, and Jelle Beekma	141
W.1.1.60	GREEN AND BLUE WATER REQUIREMENTS FOR SUSTAINABLE PAKISTAN'S STAPLE CROP PRODUCTION UNDER FUTURE CLIMATE CONDITIONS Mirza Junaid Ahmad, Gun-Ho Cho, Seulgi Lee and Kyung-Sook Choi	142
W.1.1.61	DETERMINATION OF DEPENDABLE FLOW FOR MICROHYDRO POWER PLANT IN IRRIGATION NETWORK Afida Zukhrufiyati, Joko Triyono, Segel Ginting and Eko Winar Irianto	143
W.1.1.62	REVALUATION OF LOCAL KNOWLEDGE AS A SUSTAINABLE DROUGHT ADAPTATION STRATEGY Muhamad Khoiru Zaki, Keigo Noda, Kengo Ito and Komariah	144
W.1.1.63	EVALUATION OF FARMING ACTIVITIES SUPPORTED BY CLIMATE SUB- LOANS IN TAJIKISTAN AND UZBEKISTAN DW. Shukhrat Mukhamedjanov, DW. Sherzod Mominov, Rustam Sagdullaev, and Nazokat Khasanova	145

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

W.1.2.01	WATER RESOURCE AND FOOD SECURITY: A CASE STUDY OF HOUSEHOLDS IN GAUTENG PROVINCE, SOUTH AFRICA Maponya Phokele	146
W.1.2.02	EFFECTS OF CLIMATE CHANGE ON WATER MANAGEMENT IN LOWER CHAO PHRAYA AND THA CHIN RIVERS, THAILAND Sanit Wongsu and Watchara Suiadee	148
W.1.2.03	MODELLING OF MITIGATION STRATEGIES TO REDUCE NUTRIENT LOADS TO WATERWAYS UNDER CHANGING CLIMATE AND LAND USE Richard G. Cresswell, Mark Walton and Andrew Herron	149
W.1.2.04	MEASUREMENT OF INFRASTRUCTURE PERFORMANCE IN LARGE IRRIGATION SCHEME AS A TOOL FOR ASSESSMENT OF IRRIGATION MODERNIZATION IN INDONESIA Ansita Gupitakingkin Pradipta, Murtiningrum, Sigit Supadmo Arif, Eko Subekti, Mochammad Mazid, Nadiya Isnaeni, and Anditya Sridamar Pratyasta	150
W.1.2.05	CLIMATE CHANGE IMPACT ON IRRIGATION WATER REQUIREMENT FOR PADDY Dissanayake Mudiyansele Thushara Sanjeewa Dissanayake	151
W.1.2.06	RESEARCH ON DEVELOPING FARMLAND IRRIGATION WATER MANAGEMENT MODEL IN TAIWAN Ray-Shyan Wu, Jih-Shun Liu and Yi-Chen Ruan, and Hsiang-Chuan Wu	152
W.1.2.07	REVIEW OF HEAVY METAL CONTROL STANDARDS BASED ON THE UNCERTAINTY ANALYSIS OF HUMAN HEALTH AND SOIL SUSTAINABILITY Dai-Ming Li, Pao-Hsuan Huang, Sheng-Wei Wang, Ming-Der Hong, Sheng-Hsin Hsieh and Chihhao Fan	153
W.1.2.08	APPLICATION OF INTEGRATED AUTOMATIC MONITORING SYSTEM WITH WATER SIMULATION PLATFORM ON INCREASING EFFICIENCY OF IRRIGATION WATER QUALITY MANAGEMENT Ning-Jin Kok, Shih-Chi Hsu, Ming-Der Hong, Sheng-Hsin Hsieh, Yu-Jung Hsu, and Chihhao Fan	154
W.1.2.09	WATER-ENERGY-FOOD RELATIONSHIP EVALUATION IN GREENHOUSE USING SYSTEM DYNAMICS AND SUSTAINABILITY INDEX Pureun Yoon, Jin-Yong Choi, Kwihoon Kim, Yoonhee Lee, Seung Oh Hur and Sang-hyun Lee	155
W.1.2.10	CLIMATE CHANGE IMPACT ON IRRIGATION WATER SECURITY IN WEST JAVA Waluyo Hatmoko, Brigita Diaz and Levina	156
W.1.2.11	A STUDY ON THE WATER RESOURCES ASSESSMENT FOR IRRIGATION SCHEME DEVELOPMENT IN MALAWI Sung Sick, AHN, Rae Chul, LEE and Chang Hyun, CHOI	157

W.1.2.12	INTEGRATED RIVER BASIN PLANNING AND MANAGEMENT: A CASE STUDY OF THE SOUSS MASSA RIVER BASIN, MOROCCO Karima SEBARI, Ikram Benchebani, and Marouane Amili	158
W.1.2.13	OPTIMIZATION OF SPATIAL PLANNING OF TIDAL SWAMP AREA TO SUPPORT THE COMMUNITY DEVELOPMENT OF BUOL REGENCY, INDONESIA Budi Santosa Wignyosukarto, and Hadi Santoso	159
W.1.2.14	SUSTAINABLE DRAINAGE SYSTEM OF POPULATED SITEBA AREA, CITY OF PADANG, INDONESIA Shafira Rahmadilla Hape, Budi Santoso Wignyosukarto, and Istiarto	160
W.1.2.15	CLIMATE CHANGE IMPACT ASSESSMENT ON NUTRIENT LOADING FROM PADDY AREA USING APEX-BASED CLIMATE INDEX SENSITIVITY ANALYSIS Jaepil Cho, Soongun Choi, Sewoon Hwang, and Chansung Oh	161
W.1.2.16	APPLYING KNOWLEDGE MANAGEMENT FOR IRRIGATION PERFORMANCE IMPROVEMENT IN LARGE IRRIGATION SYSTEM IN INDONESIA Murtiningrum, Andri Prima Nugroho, Sigit Supadmo Arif, Djito, and Theresia Sri Sidharti	162
W.1.2.17	INTEGRATED AGRICULTURE AND AQUACULTURE DEVELOPMENT IN BREBES COASTAL AREA, CENTRAL JAVA, INDONESIA Moh. Ali Mashuri, F.X. Suryadi, Kittiwet Kuntiyawichai and Haryo Istianto	163
W.1.2.18	APILOT STUDY ON USING PROBIOTICS TO REDUCE THE APPLICATION RATE OF NITROGEN FERTILIZER BASED ON ALTERNATE WETTING AND DRYING (AWD) IRRIGATION Joon-Keat Lai, Kuan-Hui Lin, Jia-Qi Zuo, Ying-Tzy Jou, Yu-Min Wang, and Wen-Shin Lin	164
W.1.2.19	WATER RETENTION MANAGEMENT IN LOWLANDS OF CHAO PHRAYA DELTA Thanet Somboon	165
W.1.2.20	A REVIEW OF CLIMATE CHANGE EFFECT ON GROUNDWATER IRRIGATION IN INDONESIA Rahmad Dwi Putra, Andre Putra Arifin, Ahmad Taufiq, and Anggita Agustin	166
W.1.2.21	PHOTOVOLTAIC PUMPING FOR DRIP IRRIGATION Aleman, C.C., Paes, W.G., and Ferreir A, T.S.	167
W.1.2.22	PROJECTED IMPACTS OF CLIMATE CHANGE ON MAJOR CROPS' VIRTUAL WATER IN SOUTHERN IRAN Nozar Ghahreman, Mojdeh Mohammad Rezaei, and Iman Babaeian	168
W.1.2.23	NATIONAL SCHOOL OF PLOT IRRIGATION, ECUADOR José María García-Asensio	169
W.1.2.24	ANALYSIS OF LONG-TERM CHANGE IN THE DEGREE OF TIME-CONCENTRATION OF RAINFALL IN JAPAN Kazumi Ikeyama, Takeo Yoshida and Susumu Miyazu	170
W.1.2.25	HISTORICAL SUSTAINABILITY OF GROUNDWATER IN INDUS BASIN OF PAKISTAN Ghulam Zakir Hassan Catherine Allan and Faiz Raza Hassan	171

W.1.2.26	WATER-ENERGY-FOOD RELATIONSHIP EVALUATION IN GREENHOUSE USING SYSTEM DYNAMICS AND SUSTAINABILITY INDEX Pureun Yoon, Jin-Yong Choi, Kwihoon Kim, Yoonhee Lee, Seung Oh Hur and Sang-hyun Lee	172
W.1.2.27	FORESIGHTS -TECHNOLOGIES IN THE DEVELOPMENT OF LAND IMPROVEMENT PARKS IN THE COUNTRIES - PARTICIPANTS OF EURASEC L.N. Medvedeva, D.V. Belykh, A.S. Vagner, A.V. Medvedev, P.D. Vaneeva, and I.G. Bondarik	173
W.1.2.28	REVIEW OF ALTERNATIVES FOR JAKARTA NCICD PROJECT USING NUMERICAL MODELING Park Byong Jun and Lee Jueng Chol	174
W.1.2.29	WATER TABLE VARIABILITY AND FLOW RESPONSE OF TROPICAL PEATLAND - A CASE STUDY Nilna Amal, Joko Sujono and Rachmad Jayad	175
Topic 1.3 Improvement of irrigation water productivity policy including efficient and effective water use, financing aspect, incentive and disincentive system, capacity building including non-state actors, Utilize SMART irrigation management.		
W.1.3.01	AN IMPROVED APPROACH FOR ESTIMATING SOIL MOISTURE CONTENT TO IMPROVE IRRIGATION DECISIONS Birendra KC, Henry Wai Chau, Magdy Mohssen, Keith Cameron, Majeed Safa ,Ian McIndoe, Helen Rutter, Mina Lee, Vishnu Prasad Pandey, Bart Schultz, and Krishna Prasad	176
W.1.3.02	USING SMART TECHNOLOGIES IN IRRIGATION MANAGEMENT Gadzalo Ya., Romashchenko M., Kovalchuk V., Matiash T., and Voitovich O.	178
W.1.3.03	WATER MARKET IN PAKISTAN A CASE FOR REVENUE GENERATION AND WATER SECURITY Muhammad Nawaz	179
W.1.3.04	IOT TECHNOLOGY BASED SMART WATER LEVEL PREDICTION SYSTEM IN TAIWAN TAO-YUAN MAIN CANAL Jih-Shun Liu, Ray-Shyan Wu, Chien-Kuo Chen, Jihn-Sung Lai, Hung-Chih Lee, Fang-Lan Ko, and Chia-Yi Chien	180
W.1.3.05	WATER PRODUCTIVITY OF POTATO UNDER IMPROVED IRRIGATION TECHNIQUES IN UZBEKISTAN Kakhramon Djumaboev, J. Mohan Reddy, Carlo Carli, Tulkun Yuldashev, Oytüre Anarbekov and Davron Eshmuratov	181
W.1.3.06	THE EFFECTS OF MEASURING IRRIGATION WATER USING PREPAID WATER METER ON WATER SAVING AND ENVIRONMENT: A CASE STUDY FROM TURKEY Mevlüt Aydin, Mehmet Ugur Yıldırım, Aynur Fayrap and Hakan Özdal	182
W.1.3.07	ANALYSIS OF VEGETATION INDICES FOR ESTIMATING RICE LODGING UNDER AWD IRRIGATION Tzu-Hsuan Wen, Wen-Shin Lin and Yu-Min Wang	183

W.1.3.08	MULTI CRITERIA IRRIGATION WATER ALLOCATION FOR OPTIMIZING PANDANDURI RESERVOIR OPERATION Rachmad Jayadi, FatchanNurrochmad, Abdul Azis, and Ratih Kusuma Hartini	184
W.1.3.09	IMPROVING THE WATER DISTRIBUTION UNIFORMITY BY INVESTIGATING THE HYDRAULIC PERFORMANCE OF BIG GUN SPRINKLER Tang Pan and Li Hong	185
W.1.3.10	SUSTAINABLE SUBSURFACE IRRIGATION WITH A RING-SHAPED EMITTER FOR SMALL-SCALE FARMS IN ARID REGIONS Reskiana Saefuddin, Hirota Saito, and Jiri Šimunek	186
W.1.3.11	DRIP IRRIGATION TECHNOLOGY FOR RICE CULTIVATION FOR ENHANCING RICE PRODUCTIVITY AND REDUCING WATER CONSUMPTION Soman Padmanabhan	187
W.1.3.12	IMPACT OF THE CHANGE OF SOIL TEXTURE ON THE INFILTRATION BEHAVIOR OF SOILS IN THE EARTHEN IRRIGATION CANALS OF LGDIMA AND HANABOU M. Bakache, A. Hammani, M Kuper, and E. Bartali	188
W.1.3.13	WATER-LIVELIHOOD-SUSTAINABLE AGRICULTURE APPROACH FOR ENHANCING ADAPTIVE CAPACITY TO CLIMATE CHALLENGES IN URMIA BASIN Hossain Dehghanisani, Nastaran Moosavi, Seyed Babak Moosavi Nejad, Afroz Taghizadehghasab, Neda Asadfalsafizadeh, Hamid Soltani, and Abolfazl Abesht	189
W.1.3.14	DEVELOPMENT OF OPTIMAL WATER MANAGEMENT SYSTEM FOR CULTIVATION OF HIGHCOST CROPS IN RECLAIMED FARMLAND Si Hoon Kim, Young Jun Park and Han Yong Um	190
W.1.3.15	COUNT AND ACCOUNT WATER FOR AGRICULTURAL SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT IN THE NENA REGION Jiro Ariyama, Charles Batchelor, Amgad El Mahdi, Robina Wahaj, and Domitille Vallee	191
W.1.3.16	SENSITIVITY ANALYSIS OF FARMERS' DEGREE OF FREEDOM (E) ON CANAL CAPACITY IN SECOND CLEMENT'S MODEL Shadi Ghafouri Bidgoli, and Mohammad Javad Monem	192
W.1.3.17	TRANSFORMATION OF AUSTRALIAN IRRIGATION WATER MANAGEMENT UNDER CHANGING CLIMATE Mohsin Hafeez, Ahsan Tayyab, and Muhammad Kaleem Ullah	193
W.1.3.18	WATER USE EFFICIENCY OF UNDULATED COMMAND ENHANCED BY INTEGRATION OF TANKS: CASE STUDY Bishnu Prasad Das	195
W.1.3.19	CONVERSION OF CANAL BASED IRRIGATION NETWORK SYSTEM TO PRESSURIZED PIPE BASED NETWORK SYSTEM INTEGRATED WITH SOLAR PLANT A CASE STUDY IN UTTAR PRADESH, INDIA Sabarna Roy, and Rajat Chowdhury	196

W.1.3.20	DEVELOPMENT OF PERFORMANCE EVALUATION MODEL FOR OLD AGRICULTURE INFRASTRUCTURE (FOCUS ON PUMPING AND DRAINAGE STATION) Joongu Lee, Won Choi, Sung Su Yoon and Jin Sun Park	197
W.1.3.21	ASSESSING THE IMPACT OF IRRIGATION IMPROVEMENT PROJECTS ON WATER-ENERGY-FOOD NEXUS - CASE STUDY: AL-ATF CANAL, EGYPT Talaat El Gamal and Hanan Farg	198
W.1.3.22	ASSESSING CAPACITY DEVELOPMENT NEED FOR SUSTAINABLE IRRIGATION DEVELOPMENT IN CAMBODIA Sytharith Pen, Ketya Hun, PinnaraKet, Bin Dong, Garry Ellem and Sarann Ly	199
W.1.3.23	ENABLING POLICY ENVIRONMENT: IMPROVING THE IRRIGATION WATER PRODUCTIVITY THROUGH NEW IRRIGATION POLICY IN AFGHANISTAN Suman Sijapati, Masoom Hamdard and Hashmatullah Ghafoori	200
W.1.3.24	ESTIMATION OF DAILY RUNOFF USING WATER LEVEL DATA AND OBSERVED FLOWRATE DATA Maga Kim, Jin-Yong Choi and Jehong Bang	201
W.1.3.25	IRRIGATION DEVELOPMENT IN INDIA - A FIRM STEP TOWARDS FOOD SECURITY Manoj Kumar Sinha	202
W.1.3.26	COMPARISON OF YIELDS ATTRIBUTES AND WATER PRODUCTIVITY UNDER THE SYSTEM OF RICE INTENSIFICATION (SRI) IN SOUTHERN TAIWAN S. Jean Paul Zoundou, Shiang-Min Chen and Yu-Min Wang	203
W.1.3.27	INCREASING WATER PRODUCTIVITY AND SAVING ENERGY BY HIGH YIELD RICE RATOONING IN MYANMAR Kazumi Yamaoka, Khin Mar Htay, Resfa Fitri, and Erdiman	204
W.1.3.28	CAPTURING THE IRRIGATION DYNAMICS AT FIELD SCALE IN A RICE DOMINATED BASIN USING SATELLITE REMOTE SENSING Kirthiga S.M, Narasimhan B and C. Balaji	205
W.1.3.29	NEW GEOSYNTHETIC CEMENTITIOUS CONCRETE MAT (GCCM) LINER FOR REDUCING IRRIGATION CANAL LOSSES William Crawford and Lee Church	206
W.1.3.30	PRODUCING MORE WITH LESS WATER: FROM CONCEPT TO REALIZATION BY GREEN MOROCCO PLAN Ahmed El Bouari, and Zakariae El Yacoubi	207
W.1.3.31	SUSTAINABLE WATER SAVING AND WATER PRODUCTIVITY USING DIFFERENT IRRIGATION SYSTEMS FOR COTTON PRODUCTION Oner Cetin	208

○-----○
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

- | | | |
|----------|--|-----|
| W.2.1.01 | SENSITIVITY ANALYSIS OF IRRIGATION CANAL CAPACITY WITH RESPECT TO FARMERS' DEGREE OF FREEDOM
W. Naghaee, and M. J. Monem | 211 |
| W.2.1.02 | EFFECTS OF TRAINING DURATION AND THE ROLE OF GENDER ON FARM PARTICIPATION IN WATER USER ASSOCIATIONS IN SOUTHERN TAJIKISTAN
Soumya Balasubramanya | 212 |
| W.2.1.03 | EVALUATION OF HAPPY SEEDER AS RESOURCE CONSERVATION TECHNIQUE IN LUDHIANA DISTRICT OF PUNJAB, INDIA
Devinder Tiwari, Harshneet Singh Sran, Karun Sharma, S C Sharma and Rajbir Singha | 213 |
| W.2.1.04 | ENHANCING PRODUCTION EFFICIENCY AND FARM PROFITABILITY THROUGH INNOVATIVE ENGAGEMENT PROGRAMMING
Matt C. Stockton, Daran W. Rudnick, and Chuck A. Burr | 214 |
| W.2.1.05 | REFORMS IN THE IRRIGATION SECTOR OF INDIA
K. Vohra and M. L. Franklin | 210 |

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)

- | | | |
|----------|---|-----|
| W.2.2.01 | ASSESSING CONJUNCTIVE WATER MANAGEMENT THROUGH COUPLING HUMAN AND NATURAL SYSTEM IN PAKISTAN: AN AGENT BASED MODELLING APPROACH
Mamona Sadaf, Abdul Jabbar and Asad Zaman Jelle Beekma | 215 |
| W.2.2.02 | OASIS OF CONSERVATION AGRICULTURE IN PUNJAB, INDIA: A CASE STUDY OF HAPPY SEEDER TECHNOLOGY
Devinder Tiwari, Karun Sharma, Harshneet Singh, S C Sharma, Rajbir Singh and J S Mahal | 216 |
| W.2.2.03 | WATER SCARCITY PROBLEM TREATMENT USING PRECISION IRRIGATION TECHNIQUES ON TISZA-RIVER BASIN
János Tamás, Bernadett Gálya, Florent Demelezi and Attila Nagy | 217 |
| W.2.2.04 | RESEARCH, EXTENSION SERVICES AND TRAINING AS KEY DRIVERS TO AGROFORESTRY ADOPTION IN LIMPOPO PROVINCE, SOUTH AFRICA.
Maponya P, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni AE | 218 |

W.2.2.05	MANAGEMENT MODEL OF MICRO IRRIGATION NETWORK BASED ON FARMER BUSINESS GROUPS Susi Hidayah and Santi Lestari	219
W.2.2.06	TOWARDS IMPROVED WATER USE EFFICIENCY AND PRODUCTIVITY IN COMMAND AREAS THROUGH PUBLIC PRIVATE PARTNERSHIPS – CASE OF MAHARASHTRA, INDIA Sanjay Belsare, J.V.W. Murty and Ajith Radhakrishnan	220
Topic 2.3 Promoting public-private-partnership and participation of WUA in the irrigation development and management for irrigation sustainability (i.e. to improve water efficiency and to reduce water conflict).		
W.2.3.01	ENHANCING IRRIGATION AGENCY AND WATER USERS PARTNERSHIP FOR THE REALIZATION OF A MODERN IRRIGATION SERVICE IN THE PHILIPPINES Mona Liza F. Delos Reyes and Bart Schultz	221
W.2.3.02	IRRIGATION ASSOCIATIONS AND PUBLIC-PRIVATE-PARTNERSHIP IN IRRIGATION DEVELOPMENT AND MANAGEMENT IN TURKEY Aysegul Kibaroglu	222
W.2.3.03	FARM-LEVEL PARTICIPATION OF A NOVEL WATER SAVING EDUCATION MODEL TO IMPROVE WATER USE EFFICIENCY AND IRRIGATION SUSTAINABILITY Seul Gi Lee, Bashir adelodun, Kyung Sook Choi, Jong Won Do, and Gwang Ya lee	223
W.2.3.04	DEFICIT IRRIGATION CONTRIBUTION TO IMPROVE WATER USE EFFICIENCY IN WATER SUPPLY AND UTILIZATION CHAIN Ali Akbarzadeh and Ali Shahnazari	224
W.2.3.05	PIPED DISTRIBUTION OF IRRIGATION IN SSP: MAKING SENSE OF THE CHAOS Kuhelika Ghosh, and Gyan P. Rai	226
W.2.3.06	PARTICIPATORY IRRIGATION MANAGEMENT FOR WATER CONSERVATION PROJECTS IN MAHARASHTRA, INDIA Rajesh Puranik and Mohan Narkhede	227
W.2.3.07	IMPLEMENTATION OF PARTICIPATORY IRRIGATION MANAGEMENT AND ITS ROLE IN IMPROVING THE CEREAL WATER PRODUCTIVITY – A CASE STUDY Reza Taghdisi Haydarian, and Soheila Pour Resane Manesh	228
W.2.3.08	PROMOTING PARTICIPATION FROM BENEFICIARIES IN IRRIGATION MANAGEMENT- THE CASE OF THE DAPINGDING AREA IN NANTOU COUNTY, TAIWAN Hsieh, Sheng-Hsin and Chiu,Feng-Chen	229
W.2.3.09	WATER USER ASSOCIATION AND SCHEME MANAGEMENT DEVELOPMENT UNDER THE TRANSFORMING IRRIGATION MANAGEMENT IN NIGERIA (TRIMING) PROJECT Abdullahi Abdulrahman O.	230

W.2.3.10	BIHAR MODEL OF PIM IN INDIA – SOME ISSUES L. B. Roy	231
W.2.3.11	FARMERS' PARTICIPATION IN THE TRANSITION OF THE IRRIGATION MANAGEMENT SYSTEMS: Lessons Learned from the WISMP Program Kuswanto Sumo Atmojo	232
W.2.3.12	COPING WITH CHANGE: EVOLUTION OF IRRIGATION ORGANIZATION IN TAIWAN Yu-Chuan CHANG, Ching-Tien CHEN, Sheng Hsin HSIEH, Shih-Wen CHOU, Kuang-Ming CHUANG and Ying Jian LUO	233

○-----○
**Sub-theme 3. Improving Agricultural Water Productivity with Focus on Rural
Transformation**
○-----○

**Topic 3.1 Utilizing Information Communication Technology (ICT) and innovations
for Improving water productivity and maximizing agriculture production
including smallholder farmers and indigenous people**

W.3.1.01	EFFECT OF ALTERNATE IRRIGATION ON WATER AND SALT MOVEMENT UNDER MOISTURE IRRIGATION Zhan-yu Zhanga, Wei Qi, and Ce Wang	237
W.3.1.02	OPERATIONALIZING WATER PRODUCTIVITY FOR BETTER INVESTMENT IN THE POST IRRIGATION DEVELOPMENT ERA Xueliang Cai, Yasmin Siddiqi, Jelle Beekma, and Wim Bastiaanssen	238
W.3.1.03	WATER PRODUCTIVITY OF DIFFERENT MAIZE CULTIVARS WITH SUBSURFACE DRIP IRRIGATION Fatemeh Heydari, Teymor Sohrabi, Hamed Ebrahimian and Hossein Dehghanisanij	239
W.3.1.04	VALIDATION OF REMOTE-SENSING EVAPOTRANSPIRATION DATA OF SELECTED CROPS IN THE NILE DELTA Atef Swelam, Ajit Govind, Mohamed Abdallah, Pasquale Steduto and Ahmad Taha	240
W.3.1.05	A NUMERICAL MODEL FOR HYDRAULIC ENTIRE IRRIGATION CANAL SYSTEM Natsuki Buma, Tetsuo Nakaya, Issaku Azechi, Masaomi Kimura and So Fujiyama	241
W.3.1.06	A DECISION SUPPORT SYSTEM FOR MATCHING IRRIGATION DEMAND AND SUPPLY IN A NEAR REAL TIME ENVIRONMENT Mohsin Hafeez, Mahmood Ali Khan and Mohammad Kaleem Ullah	242
W.3.1.07	VOLUMETRIC CONTROL FOR CONTRASTING REMOTE-SENSING, IN SUPPORT OF HYDROLOGICAL PLANNING IN SPAIN Tatiana Ortega, Jesús Garrido, Alfonso Calera and Concepción Marcuello	243
W.3.1.08	MEASURING SATURATED SOIL HYDRAULIC CONDUCTIVITY IN CULTIVATED AREA OF THE IRRIGATION PROJECTS IN THAILAND Pattarapong Teerapunyapong, Areeya Rittima, Yutthana Phankamolsil, and Yutthana Talaluxmana	244

W.3.1.09	A SIMPLE METHOD TO EVALUATE THE TOTAL PATROL LENGTH OF PADDY FIELD PLOTS FOR IRRIGATION WORK Toshiaki Iida, Mutsuki Sakai, Masaomi Kimura and Naritaka Kubo	245
W.3.1.10	GROUNDWATER FLOW MODELLING FOR THE DEVELOPMENT OF MANAGED AQUIFER RECHARGE SCHEME IN IRRIGATION PROJECTS, THAILAND Sasipong Rantaseewee, Areeya Rittima, Yutthana Phankamolsil, and Yutthana Talaluxmana	246
W.3.1.11	NARAYANPUR LEFT BANK CANAL AUTOMATION PROJECT Sidharth Charkha and V.D. Loliyana	247
W.3.1.12	EFFECT OF IRRIGATION, CHEMICAL FERTILIZATION, AND PROBIOTICS IN RICE FIELDS SOIL PROPERTIES Raudha Anggraini Tarigan, Yu Ting Weng, Yu Min Wang and Ying TzyJou	248
W.3.1.13	ADAPTATION OF INNOVATIVE INTERVENTIONS FOR ENHANCEMENT OF WATER USE EFFICIENCY: AN EXPERIENCE OF FARMERS' EMPOWERMENT IN SSPC R.B. Maraviya, C.R. Patel, M.M. Vaghasiya, and M.M. Patel	249
W.3.1.14	OPTIMAL OPERATION OF IRRIGATION CANAL NETWORK SYSTEM USING SWMM Na-Kyoung Bang, Won-Ho Nam, Hyun-Uk An, Tae-Hyun Ha, and Kwang-Ya Lee	250
W.3.1.15	FLYING SENSORS FOR SMALLHOLDER FARMING: AN INNOVATIVE TECHNOLOGY FOR WATER PRODUCTIVITY ASSESSMENT Jonna D. van Opstal, Alexander Kaune, Corjan Nolet, Jan van Til, and Johannes E. Hunnink	251
W.3.1.16	IRRIGATION MODERNIZATION BASED ON PRECISION AGRICULTURE AND CITY FARMING CONCEPT Andri Prima Nugroho, Sigit Supadmo Arif and Murtiningrum	252
W.3.1.17	USING SMALL SCALE DESALINATION BY CAPACITIVE EIONIZATION (CDI) TO IMPROVE CROP YIELD AND PROFITABILITY IN LOCATIONS WITH BRACKISH GROUNDWATER Clare Bales, John Fletcher and T. David Waite	253
W.3.1.18	IMPROVING AGRICULTURAL PRODUCTIVITY AND WATER USE EFFICIENCY THROUGH PER DROP MORE CROP SCHEME Pankaj Tyagi and Manish Singh	254
W.3.1.19	NEW STRATEGY TO DRASTICALLY INCREASE WATER PRODUCTIVITY THROUGH HIGH YIELDING PERENNIAL RICE RATOONING IN GHANA Kazumi Yamaoka and Joseph Ofori	255
W.3.1.20	WATER USE EFFICIENCY AND PRODUCTIVITY IN PADDY FIELD UNDER SUBSURFACE DRAINAGE TECHNOLOGY WITH SHEET-PIPE SYSTEM Chusnul Arif, Budi Indra Setiawan, Satyanto Krido Saptomo, Hiroshi Matsuda, Koremasa Tamura, Youichi Inoue, Zaqiah Mambaul Hikmah, Nurkholish Nugroho, and Nurwulan Agustiani	256
W.3.1.21	REGULATORY APPROACH FOR SUSTAINABLE WATER RESOURCE MANAGEMENT IN THE STATE OF MAHARASHTRA (INDIA) K. P. Bakshi and Vinay Kulkarni	258

W.3.1.22	APPLICATION OF DEEP LEARNING TECHNIQUE FOR THE DEVELOPMENT OF A WATER MANAGEMENT TOOL FOR SMALL IRRIGATION RESERVOIRS Daisuke Hayashi, Tsumugu Kusudo, Daisuke Matsuura, Yutaka Matsuno, and Nobumasa Hatcho	259
W.3.1.23	DEVELOPMENT OF FARM-CANAL COOPERATIVE WATER MANAGEMENT SYSTEM WITH ICT Tetsuo Nakaya, Atsusi Namihira and Hiroyuki Taruya	260
W.3.1.24	IMPROVING AGRICULTURAL WATER PRODUCTIVITY THROUGH RURAL COMMUNITY PARTICIPATION AND IMPROVEMENT OF FARMERS' FARMLAND MANAGEMENT (CASE STUDY: URMIA LAKE BASIN) Hossain Dehghanisani, Majid Mirlatifi, Vahidreza Verdinejad, Fereshteh Batoukhteh, Mohsen Soleymani Roozbahani, and Yosefali Ahmadi Mamagani	261
W.3.1.25	PERFORMANCE OF RING IRRIGATION SYSTEM FOR MELON BREEDING IN A GREENHOUSE Satyanto Krido Saptomo, Willy Bayuardi Suwarno, Heru Anggara, Yanuar Chandra Wirasembada, and Budi Indra Setiawan	262
W.3.1.26	USE OF DRONE FOR EFFICIENT WATER MANAGEMENT: A CASE STUDY Pravin Kolhe and T. N. Munde	236

Topic 3.2 Optimizing value of water through integrated farming and market driven agriculture (i.e. labour per m³, revenue per m³, nutrition per m³ etc), enhancing value chain of irrigation water to promote social economic community transformation (i.e. multifunction use of irrigation water, etc.).

W.3.2.01	IRRIGATION WATER PRICING UNDER CONJOINED WATER, SALINITY AND NITROGEN STRESSES Farimah Omidj, and Mehdi Homaei	263
W.3.2.02	ENHANCING WATER PRODUCTIVITY IN WHEAT THROUGH IN-SITU RICE RESIDUE RETENTION BY HAPPY SEEDER IN NORTH-WESTERN INDIA Rajbir Singh and A.K.Singh	264
W.3.2.03	DROUGHT ANALYSIS TO SUPPORT URBAN AGRICULTURE IN WANGGU CATCHMENT AREA, INDONESIA Fajar Baskoro Wicaksono, Arbor Reseda, Eka Nugraha Abdi and F.X. Suryadi	265
W.3.2.04	AT FARM LEVEL UNDER PUBLIC AND CIVIL CANAL IRRIGATION SYSTEMS IN PESHAWAR VALLEY Rabnawaz, Muhammad Jamal Khan, Tahir Sarwar, and Muhammad Jamal Khan	266
W.3.2.05	COMMUNITY WATER RESOURCES MANAGEMENT IN THAILAND Chataramongkol Singhawiboon, Wongsathit Boonthunyakorn, and Jumpol Nimpanich	267

W.3.2.06	APPLYING APSIM FOR EVALUATING INTERCROPPING UNDER RAINFED CONDITIONS: A PRELIMINARY ASSESSMENT Vimbayi Grace Petrova Chimonyo, Albert Thembinkosi Modi, and Tafadzwanashe Mabhaudhi	268
W.3.2.07	IMPACT OF JAIN IRRIGATION'S AGRI BUSINESS MODEL ON ENVIRONMENT Dilip N. Kulkarni	269
W.3.2.08	WATER AND ENERGY FOOTPRINT IN A DRIP IRRIGATED AND SPRINKLER FROST PROTECTED BLUEBERRY CROP IN CONCORDIA, ARGENTINA Alejandro Pannunzio, Eduardo Holzapfel, Pamela Teixeira, Javier Brenner, Francisco Dufour, and Gerardo Demarco	270
W.3.2.09	NUTRIGATION TO ENHANCE THE CROP YIELD BY SOLAR POWER Kinge Manisha, Pachpande Sagar, and Yewalekar Dilip	271
W.3.2.10	AGRICULTURAL REVISION IN DROUGHT PRONE ARID REGION OF KUTCH: PEOPLE LED, MARKET ORIENTED GROWTH UNDER ADVERSE CLIMATIC CONDITIONS Praharsh Patel	272
W.3.2.11	SPECIALIZED NITROGEN FOR IRRIGATED CANOLA (BRASSICA NAPUS) IN SASKATCHEWAN Gary Kruger, PAg, Joel Peru, PAg, Garry Hnatowich, Scott Anderson, Rigas Karamanos, Kaitlyn Gifford, and Murray Kasper	273

Topic 3.3 Financial scheme and access development for improving agricultural water productivity in alleviating poverty in rural area.

W.3.3.01	NAGARJUNA SAGAR PROJECT – MODERNIZATION FOR IMPROVING WATER MANAGEMENT THROUGH WARABANDI (ON/OFF) SYSTEM S. Suneel and V.Narasimha	274
W.3.3.02	OPTIONS FOR IMPROVING AGRICULTURAL WATER PRODUCTIVITY UNDER INCREASING WATER SCARCITY IN SOUTH AFRICA Tafadzwanashe Mabhaudhi, Sylvester Mpandeli, Luxon Nhamo, Aidan Senzanje Vimbayi Grace Petrova Chimonyo, and Albert Thembinkosi Modi	275
W.3.3.03	MISSION KAKATIYA – FOR RESTORATION OF TANKS AND WATER BODIES IN TELANGANA Deshpande Sridhar Rao, Veerabomma Ajay Kumar, and Menaka Devender	276
W.3.3.04	GOVERNANCE OF INVESTMENT IN PUMPED DRAINAGE IN WATER LOGGED POLDERS Stijn Reinhard, Toine Vergroesen and Femke Schasfoort	277
W.3.3.05	ASSESSMENT OF IRRIGATION WATER PRICE FOR RICE AND WHEAT CROPS IN INDIA A. Upadhyaya, and L.B. Roy	278
W.3.3.06	EVALUATION OF FARMING ACTIVITIES SUPPORTED BY CLIMATE SUB-LOANS IN TAJIKISTAN AND UZBEKISTAN Shukhrat Mukhamedjanov, Sherzod Mominov, Rustam Sagdullaev, and Nazokat Khasanova	279

W.3.3.07	MORE CROP PER DROP THROUGH KEN BETWA RIVER LINK SYSTEM Rajesh Kumar Jain	280
W.3.3.08	MODULAR WEIR: NEW METHOD OF WEIR CONSTRUCTION TO IMPROVE IRRIGATION PRODUCTIVITY James Zulfan, Slamet Lestari, Ririn Ririn Rimawan, Marta Nugraha Hidayat, and Nuryanto Sasmito Slamet	281
W.3.3.09	SUSTAINABLE AGRICULTURAL GROWTH FOR THE RURAL DEVELOPMENT IN ASIA: A REVIEW Kyung Sook Choi, and Vijay K Labhsetwar	282
W.3.3.10	TAIL TO HEAD: A TECHNIQUE IN IMPROVING WATER USER EFFICIENCY AND PRODUCTIVITY OF SRIRAM SAGAR PROJECT TELANGANA STATE (INDIA) Bhuram Shankar, Punnana Nagabhushana Rao, and Bejjanki Sravan Kumar	283
W.3.3.11	THE PRIVATE PUBLIC PARTNERSHIP A STRATEGIC CHOICE FOR EFFICIENT AND SUSTAINABLE IRRIGATION MANAGEMENT IN MOROCCO A. El Bouari, M. Ouhssain, S. Oudrhiri, and R. tanji	284



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

Nilna Amal¹, Joko Sujono² and Rachmad Jayadi³

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; Wösten et 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

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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 (Murdiyarsa 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 km². Geographically Kepulauan Meranti district 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

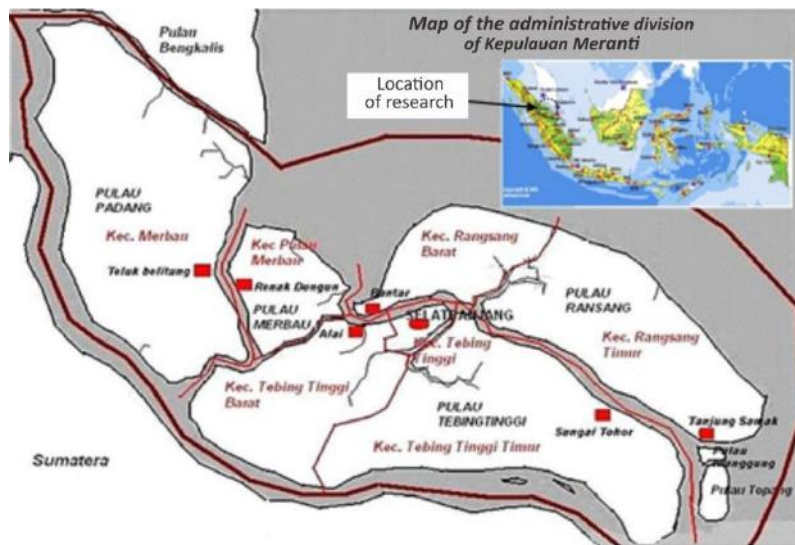


Figure 1. Location of research

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 peatland 100-200 cm called middle dome
3. Thickness of peatland 200-300 cm called deep dome
4. Thickness of peatland 200-300 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 km² includes Tanjung Padang Wildlife Reserve /Suaka Margasatwa Tanjung Padang 48.57 km², PT GCN Pulau Padang licensed restoration range 204.37 km², and PT RAPP licensed permit area 94.17 km². 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 of conservation 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 3 and Figure 4 below.

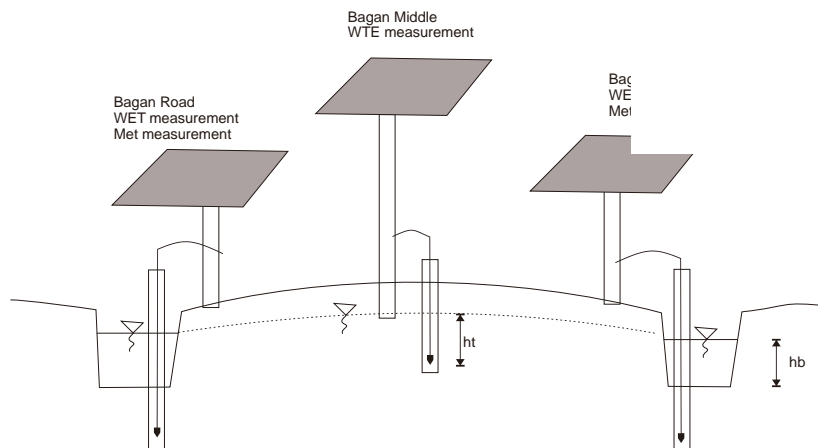


Figure 3. Sketch of the measurement



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.

$$\Delta S = P - ET - RO - I$$

where:

- P :rainfall (mm/day),
- ET : evapotranspiration (mm/day),
- RO :surface flow (mm/day),
- I : infiltration (mm/day),
- ΔS :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:

- ΔS :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. $1.8 = (22/5621 \times 100\%) = 0.39\%$.
 - b. $1.7 = ((22+37)/5621 \times 100\%) = 1.05\%$ 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%.

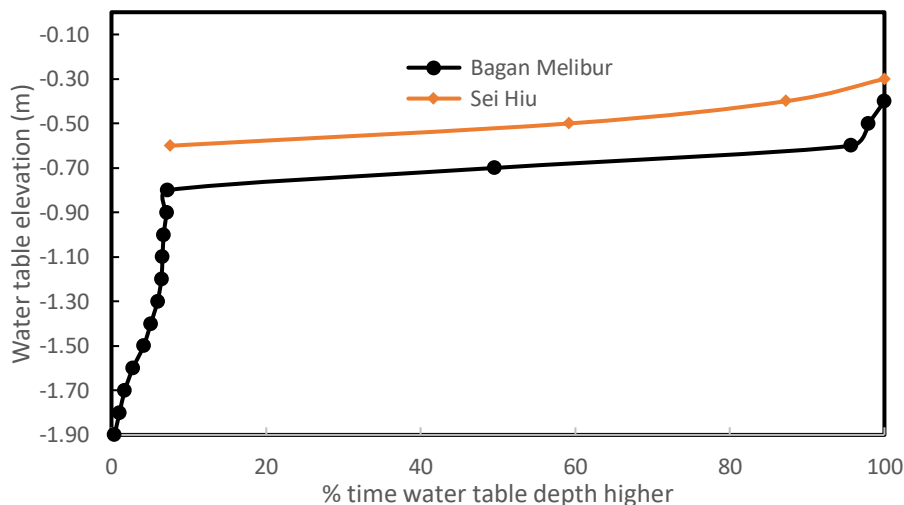


Figure 5. Water table frequency curves for Bagan Melibur dan Sei Hiu

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 November 6th 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.

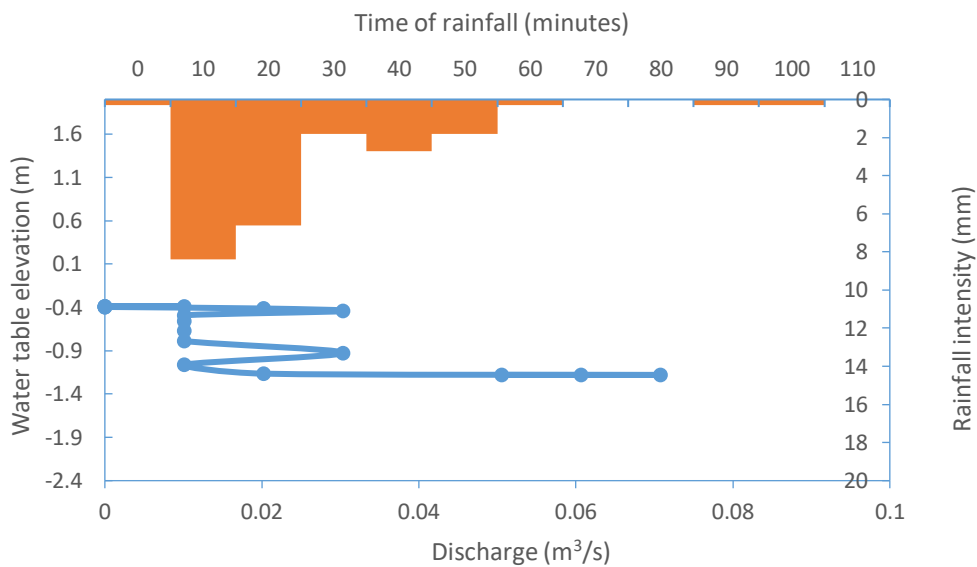


Figure 6. Profile of rainfall and discharge vs water table elevation on November 6th 2017.

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 m³/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.

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