



**1st international symposium on Integrated Flood and
Sediment Management in River Basin
for Sustainable Development** **2022**

FSMaRT

ABSTRACTS

**18-20th December 2022, R. S02.06 – Smart Building, DUT
Da Nang, Viet Nam**

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Symposium Agenda of 1st FSMaRT 2022

Time		Activity
1st day of FSMaRT2022 (Sunday, 18th of December)		
1	08:30 – 09:00	Registration
2	09:00 – 09:30	Opening Session
	09:00 – 09:05	Welcome Message from Assoc. Prof. Duong Vo Ngoc (Da Nang University of Science and Technology, Vietnam)
	09:05 – 09:10	Special Message from Mr. Suzuki Takashi (JICA representative in Vietnam)
	09:10 – 09:15	Special Message from Mr. Nobuyuki Ichihara (Director International Affairs Division, Japan Water Agency)
	09:15 – 09:20	Special Message from Prof. Ricmar P. Aquino (President of Isabela State University, Philippines)
	09:20 – 09:25	Special Message from Prof. Tetsuya Sumi (Kyoto University, Japan)
	09:25 – 09:30	Special Message from Prof. Thai Nguyen Canh (Thuyloi University, Vietnam)
	09:30 – 09:35	Special Remarks from Assoc. Prof. Doan Quang Vinh (The Rector of the Da Nang University of Science and Technology, Vietnam)
3	09:35 – 09:50	Final Report of Research Achievements of Integrated Flood and Sediment Management (FSMaRT) by Prof. Sameh Kantoush
	09:50 – 10:00	MOU Signature between Isabela State University and Da Nang University of Science and Technology
4	10:00 – 10:15	Group Photo and Coffee Break
5	10:15 – 10:30	Keynote #1: Situation over Vu Gia-Thu Bon (VGTB), Vietnam by Dr. Nguyen Van Hoang , Vietnam disaster management authority
	10:30 – 10:45	Keynote #2: Prof. Tetsuya Sumi , Kyoto University, Japan
	10.45 – 11.30	Open Session for Plenary Discussion



3rd day of FSMaRT2022
(Tuesday, 20th of December)

Field Excursion

08.00	1 st Meeting Place at Hotel Lobby
08.15	2 nd Meeting Place at University of Science and Technology
09:15	Departure from University of Science and Technology by bus
11:15	Arrival at A Vuong Hydropower at Thanh My Town, Nam Giang District, Quang Nam
12:30	Lunch
13:00	Departure from A Vuong Hydropower
14:30	Arrival at CuaDai river mouth in Cam An ward, Hoi An city, Quang Nam province
16:45 – 18:30	Visit Hoi An Ancient town, Japanese bridge, Tan Ky ancient house, Phuc Kien Assembly hall, Museum of Trade Ceramics, CamPho communal house, etc
18:30	Dinner
19:00	Return to Danang city
20:00	Arrival at Danang city

Detailed Program of 1st FSMaRT 2022

18th December 2022 (Sunday), at the Conference Hall of F Building

08:30 – 09:00	Registration	
Opening Sessions		
Chaired by: Prof. The Hung Nguyen		
Time	Title of presentation	Presenter
09:00 – 09:05	Welcome Message	Assoc. Prof. Duong Vo Ngoc, (Da Nang University of Science and Technology, Vietnam)
09:05 – 09:10	Opening Speech	Mr. Suzuki Takashi (JICA representative in Vietnam)
09:10 – 09:15	Opening Speech	Mr. Nobuyuki Ichihara (Director International Affairs Division, Japan Water Agency)
09:15 – 09:20	Opening Speech	Prof. Ricmar P. Aquino (President of Isabela State University, Philippines)
09:20 – 09:25	Opening Speech	Prof. Sameh A. Kantoush (DPRI, Kyoto University, Japan)
09:25 – 09:30	Opening Speech	Prof. Thai Nguyen Canh (Thuyloi University, Vietnam)
09:30 – 09:35	Special Remarks	Assoc. Prof. Doan Quang Vinh, (The Rector of the Da Nang University of Science and Technology, Vietnam)
09:35 – 09:50	Final Report on Research Achievements of Integrated Flood and Sediment Management (FSMaRT)	Prof. Sameh A. Kantoush (DPRI, Kyoto University, Japan)
09:50 – 10:00	MOU Signature between Isabela State University and Da Nang University of Science and Technology	
10:00 – 10:15	Group Photo and Coffee Break	
Special Session		
Chaired by: Prof. Sameh A. Kantoush		
Time	Title of presentation	Presenter
10:15 – 10:30	1#: Keynote Speaker	Dr. Nguyen Van Hoang (Vietnam disaster management authority)
10:30 – 10:45	2#: Keynote Speaker	Prof. Tetsuya Sumi (DPRI, Kyoto University, Japan)
10:45 – 11.30	Open Session for Plenary Discussion	

Poster Program – Session A B (11.30 -12.00)

Chaired by: Dr. Son Truong Hong

Note: Allocated time for Poster Presentations: 03 min. talk + 02 min. discussion

Poster Code	Title	First Author/Presenter
A1	Impact assessment of Son Tra wastewater treatment to the coast of Danang city, Vietnam	Nguyen Phuoc Quy An
A2	Application of Rainfall-Runoff Inundation model to forecast Magat dam inflow and water elevation	Arlen Alejandro
A3	Ceres – A Citizen Science Approach Monitoring Reservoir Operation from space for poorly gauged reservoirs: A case study in Vu Gia Thu Bon.	Tien Du
A4	Vulnerability assessment of riverbank erosion: a case study of Vietnamese Mekong Delta	Menna Ahmed
A5	Hydropeaking process in Vu Gia Thu Bon River basin: Causes, consequences, and main driven	Binh Quang Nguyen
A6	Reviewing on flood simulation using hydrological models	Son Nguyen Thien
A7	Monitoring the shoreline change in the coastal area of Da Nang City, Vietnam using time-series satellite imageries and Google Earth Engine platform	Van An Nguyen
A8	Evaluation of urbanization and climate change on urban water drainage system in central of Vietnam	Duc Phuoc Vo
12:00 – 13:00	Extension of Poster Session with Lunch	

1st Session on Hydrological Modelling and Sediment Management – A
Chaired by: Prof. Mohamed Saber

Note: *Allocated time for Oral Presentations: 15 min. talk*

Time	Title of presentation	First Author/Presenter
13:00– 13:15	Comparison of 2D and 3D modelling for T-junction channel with different turbulence model	Mohamad Faizal Ahmad
13:15 – 13:30	Sediment Nutrient Fluxes and Links to Harmful Algal Blooms in a Eutrophic Lake using Diagenetic Modeling	Phuong Doan
13:30 – 13:45	Riverbank erosion assesment usung Mike 21C modeling in Vu gia – Thu Bon river (Quang Nam provincial region)	Tuan An Bui
13:45– 14:00	Overview of reservoir sedimentation in Batu Dam, Selangor, Malaysia	Siti Saimah Abdul Rahman
14:00 – 14:15	Dynamic of Salinity Intrusion in CoChien and CungHau branches of Mekong estuaries	Nguyen Phuong Mai
14:15 – 14:30	Open Discussion (Q&A)	

2nd Session on Hydrological Modelling and Sediment Management - B
Chaired by: Dr. Doan Van Binh

Note: *Allocated time for Oral Presentations: 15 min. talk*

Time	Title of presentation	First Author/Presenter
14:30 – 14:45	Impacts of Reservoirs on Sediment concentration in the transboundary Srepok River Basin, Vietnam	Thao Bui Thi Phuong
14:45 – 15:00	Integrated flood and sediment management in river basins for sustainable development: The case of Cagayan River Basin	Lanie Alejo
15:00 – 15:15	A conceptual approach to study influences of river sand mining on the depth-averaged velocity in vegetated compound channels	Son Hong Truong
15:15 – 15:30	Optimization of Magat dam operation rule for flood risk management in the Cagayan river basin	Hikaru Goto

15:30 – 15:45	Magat Dam science-based initiatives for long-term flood and sediment management	Carlo Ablan
15:45 – 16:00	Open Discussion (Q&A)	
16.00 – 16.15	Coffee Break	
3rd Session on Artificial Intelligence for Hydrological Application <i>Chaired by Dr. Pham Hong Nga</i>		
<i>Note: Allocated time for Oral Presentations: 15 min. talk</i>		
Time	Title of presentation	First Author/Presenter
16.15 – 16.30	Water level prediction model of Kien Giang river based on regression techniques	Quang Chieu Ta
16.30 – 16.45	Water level prediction of Kien Giang river using deep learning models	Trung Hieu Trieu
16.45 – 17.00	A real-time flood forecasting hybrid machine learning hydrological model for Krong H'rang hydropower reservoir	Phuoc Sinh Nguyen
17.00 – 17.15	Machine Learning Techniques and hydrological Modeling for Flood Susceptibility and Inundation Mapping: Case study VGTB River Basin, Vietnam	Mohamed Saber
17.15 -17.30	Open Discussion (Q&A)	
18.00 – 20.00	1st Day Dinner	

19th December 2022 (Monday), at the Conference Hall of F Building

Special Session <i>Chaired by: Prof. Tetsuya Sumi</i>		
Time	Title of presentation	Presenter
09:00 – 09:15	3#: Keynote Speaker	Prof. Orlando F. Balderama (Isabela State University, Philippines)
09:15 – 09:30	4#: Keynote Speaker	Prof. Hung The Nguyen (University of Science and Technology in Danang, Vietnam)
09.30 – 09.45	Coffee Break	

4th Session on Flood Risk Assessment
Chaired by: Prof. Orlando Balderama

Note: *Allocated time for Oral Presentations: 15 min. talk*

Time	Title of presentation	First Author/Presenter
09:45 – 10:00	Urban flood forecasting based on hydraulic model by coupling of MIKE Flood and MIKE Urban: A case study of Tam Ky city, Vietnam	Cong Nguyen Chi
10:00 – 10:15	Flood modelling in the Ba River basin using a coupled hydrodynamic model - MIKE FLOOD	Tuan Luc Anh
10:15 – 10:30	Study on flood mitigation operation of cascading dams, including hydropower dams in Ohi river	Yuki Okamoto
10:30 – 10:45	Flood Vulnerability Indicators of Transportation System Concerning Climate Change	Hamizah Amalina Amlan
10:45 – 11:00	Stakeholders forum on integrated flood risk management in Cagayan River Basin: Basis in writing policy recommendations	Orlando Balderama
11:00 – 11:15	Development of a localized integrated disaster risk index – A Malaysia case study of Langat River Basin	Muhammad Wafiy Adli Ramli
11:15 – 11:30	Open Discussion (Q&A)	

Poster Program- Session B (11.15 -12.00)

Chaired by: Dr. Pham Hong Nga

Note: *Allocated time for Poster Presentations: 03 min. talk + 02 min. discussion*

Poster Code	Title	First Author/Presenter
B1	Mapping Open Fire Susceptibility and Nearest Water Resources For Fire Fighting -A Case Study in Johor Malaysia	Fara Aiza Md Sanin
B2	Response of long-term hydrological to land use/land cover change in Vu Gia Thu Bon River basin	Thanh-Nhan-Duc Tran

B3	Modeling the urban flood during the heavy rain in October 2022 for Ngu Hanh Son District, Da Nang City using SWMM model	An Tran
B4	Nonparametric estimation approach for evaluating the trend of hydro-meteorological factors in Lại Giang, Binh Dinh.	Thi Ngoc Canh Doan
B5	Impacts of drought on water resources in Central Vietnam. A case study of Vu Gia– Thu Bon River basin	Binh Quang Nguyen
B6	Quantification of GPM IMERG and SM2RAIN-ASCAT rainfall products over complex terrain under impacts of reservoirs. A case study for Srepok River basin	Thanh-Nhan-Duc Tran
B7	River System's Behavioral Changes: Response to Climate Change or Manmade?	Kogila Vani Annammala
B8	Analysis of spatial and temporal variation in rainfall trend of Vu Gia Thu Bon River Basin, Vietnam	Thao Bui Thi Phuong
B9	Spatio-temporal variability and trends of extreme rainfall and temperature events over Cagayan River Basin, Philippines	Khagendra Bharambe
B10	Trends of low flow in the Vu Gia - Thu Bon river basin, Central Vietnam	Thi Ngoc Uyen Nguyen
12:15 – 13:00	Extension of Poster Session with Lunch	
5th Session on Remote Sensing and GIS for Flood and Water Security Chaired by: Prof. Thai Nguyen Canh		
Note: <i>Allocated time for Oral Presentations: 15 min. talk</i>		
Time	Title of presentation	First Author/Presenter
13:00 – 13:15	Evaluation of water indices for dynamic monitoring reservoir surface water using Landsat 8 data	Anh Minh Vu

13:15 – 13:30	Impact of different types of vegetation in reducing roof runoff	Noraliani Alias
13:30 – 13:45	Impacts of anthropogenic activities on riverbed elevation. A case study in Central Vietnam	Binh Quang Nguyen
13:45 – 14:00	Livelihood resilience: salinity intrusion hazard assessment of and adaptation strategy for socio-economic development in Ben Tre Province	Doan Van Binh
14:00 – 14:15	GIS-based flood susceptibility mapping using AHP approach: A case study of Kien Giang river basin, Quang Binh province	Ngan Vu Huong
14:15 – 14:30	Open Discussion (Q&A)	
6th Session on Hydrological Modelling and Sediment Management - C Chaired by Dr. Nor Eliza Alias		
<i>Note:</i> <i>Allocated time for Oral Presentations: 15 min. talk</i>		
Time	Title of presentation	First Author/Presenter
14.30 – 14.45	Hydrodynamic modelling of Magat dam and reservoir during extreme conditions using Telemac 2D	Jeoffrey Lloyd R. Bareng
14.45 – 15.00	Evaluation of coastline change in Quang Nam under the influence of jetty construction	Tran Tieu Long Trinh
15.00 – 15.15	Evaluation of hydrodynamic and sediment transport under construction of Cua Lo’s navigation channel	Cong Phuc Dang
15.15 – 15.30	Two-dimensional numerical models in simulating hydro-sediment-morphodynamics for the Vu Gia Thu Bon River basin	Binh Quang Nguyen
15.30 – 15.45	Assessment of salinity intrusion trends along main rivers and coastal zones in the Vietnamese Mekong Delta	Doan Nguyen Luyen Phuong
15.45 – 16.00	Open Discussion (Q&A)	

7th Session on Climate Change and Sustainability
Chaired by Prof. Hung The Nguyen

Note: *Allocated time for Oral Presentations: 15 min. talk*

Time	Title of presentation	First Author/Presenter
16.00 – 16.15	Assessment of water scarcity under the impact of climate change in the downstream Vu Gia Thu Bon river basin, Vietnam	Mai Thi Thuy Duong
16.15 – 16.30	Probable maximum precipitation estimates considering homogeneous regions of Malaysia	Nor Eliza Alias
16.30 – 16.45	Climate change intensifies drought vulnerability of magat sub basin in the Philippines	Christian Alec Managa
16.45 – 17.00	Open Discussion (Q&A)	
Awards and Closing Remarks		
17.00 – 17.30	Presentation of Awards and Closing Remarks	
18.30 – 21.00	2nd Gala Dinner at Hotel	

Committee for Poster: *Prof. Mohamed Saber, Dr. Doan Van Binh, Dr. Pham Hong Nga, Dr. Lanie Alejo*

3rd day of FSMaRT2022
(Tuesday, 20th of December)

Field Excursion

08.00	1 st Meeting Place at Hotel Lobby
08.15	2 nd Meeting Place at University of Science and Technology
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11:15	Arrival at A Vuong Hydropower at Thanh My Town, Nam Giang District, Quang Nam
12:30	Lunch
13:00	Departure from A Vuong Hydropower
14:30	Arrival at CuaDai river mouth in Cam An ward, Hoi An city, Quang Nam province
16:45 – 18:30	Visit Hoi An Ancient town, Japanese bridge, Tan Ky ancient house, Phuc Kien Assembly hall, Museum of Trade Ceramics, CamPho communal house, etc
18:30	Dinner
19:00	Return to Danang city
20:00	Arrival at Danang city

1st Session on Hydrological Modelling and Sediment Management – A

Impact assessment of Son Tra wastewater treatment to the coast of Danang city, Vietnam

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Abstract. Son Tra wastewater treatment plant (WWTP) is one of four WWTPs in Danang City. In most of the cases, the wastewaters are treated by WWTPs before discharging into the natural environment that is the coastal area or rivers. However, the treatment level does not ensure a sufficient performance for maintaining the quality of the receptive environment. This situation is currently faced in the Danang area where the significant impact has been detected in the receiving environment. In this study, Mike 21 FM Hydrodynamics module coupled to a water quality model using Mike 21 FM ECOLab module is applied to simulate the water quality and to identify the spreading of NH_4^+ , which is used as a pollutant tracer. The study suggests three scenarios of NH_4^+ concentration in the wastewater of the Son Tra WWTP outlet are used to simulate the impact in the coastal area. The first scenario is that wastewater discharges from the outlet with the current NH_4^+ concentration (15 mg/l). Second, after some failure with Son Tra WWTP because of power outage or damages, therefore, wastewater discharge directly to the coast with a higher NH_4^+ concentration (25 mg/l) for 24 hours. Third, wastewater is treated to follow the regulation of industrial wastewater (10 mg/l). Out of the three proposed scenarios, the polluted area of scenario 1 is similar to scenario 2. However, scenario 2 generates the largest polluted area with NH_4^+ concentration > 1.9 mg/l. Scenario 3 has the smallest polluted area along the coast and the NH_4^+ peak concentration is lower than 1.7 mg/l.

Keywords. Son Tra WWTP, NH_4^+ concentration, Mike 21 FM ECOLab, coastal area, scenario

Application of Rainfall-Runoff Inundation model to forecast Magat dam inflow and water elevation

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Tetsuya Sumi⁵, and Sameh Ahmed Kantoush⁶

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Short abstract. Flood forecasting is vital in preventing and mitigating flood damage. Flood inundation can be simulated to forewarn the affected areas of the possible effect of floods brought by heavy rainfall events. Rainfall-runoff models need precise forecast rainfall. In this paper, the fully calibrated and validated Rainfall-Runoff Inundation Model utilized the 3-ensemble rainfall forecast that gives high, mid, and low forecast scenarios. It was tested on extreme weather events, typhoon Karding and Maymay. The result shows RRI simulated inflows and statistical values indicate unacceptable agreement with the actual inflow. However, it was satisfactory in terms of predicted water level. The ensemble is yet to be bias corrected. Generally, the use of the hourly prediction from the ensemble gave quite good results when translated to inflow and water elevation using the RRI.

Keywords. Forecasting, runoff, ensemble

Ceres – A Citizen Science Approach Monitoring Reservoir Operation from space for poorly gauged reservoirs: A case study in Vu Gia Thu Bon.

Du Le Thuy Tien¹, Hyongki LEE¹, Duong Du Bui², Son K. DO^{1,*}, Ngoc Thi Nguyen¹, Thao Thi Phuong Bui³, Nuong Thi Bui⁴, Tra T.T. NGUYEN²

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Abstract. This study creatively employs a well-known citizen science approach to constantly further improve our satellite based reservoir operation monitoring (CERES) tool, enhance end-users' trust, acceptance and uptake of the tool and consequently support water resources decision making processes for users. Our CERES is a cloud-based interactive web app with freely available datasets for non-commercial uses based on multi-mission satellite datasets, including Sentinel-1 C-band Synthetic Aperture Radar Ground Range Detected (SAR GRD), Shuttle Radar Topography Mission (SRTM) Digital Elevation Models (DEM), Advanced Land Observing Satellite (ALOS) and Multi-Error-Removed Improved-Terrain (MERIT) DEM. Its graphical user interface design allows non programming users to interact with maps, generate results, evaluate them with provided templates and optionally email performance metrics and figures back to developers for further improvement without granting developers of access to the local observed data.

Keywords. Monitoring, remote sensing, citizen science, reservoirs, poorly-gauged, Vu Gia Thu Bon River basin

Vulnerability assessment of riverbank erosion: a case study of Vietnamese Mekong Delta

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Abstract. Over decades, the Vietnamese Mekong Delta (VMD) has suffered severe coastal and riverbank erosions resulting in serious social, economic, and environmental impacts. Several natural and anthropogenic key factors contribute to the rising riverbank erosion rate in VMD, such as flood depletion, rainfall extremes, high water waves and currents, soft alluvial soils, excessive sand mining, increasing river traffic, and sediment reduction caused by upstream river damming. Although few studies have estimated the long-term riverbank erosion in VMD using remote sensing and numerical models, no study has assessed the eroded sediment volume due to the riverbank. In this paper, we quantitatively evaluated the eroded volumes due to riverbank erosion along VMD by field survey, remote sensing, and a two-dimensional (2D) hydromorphodynamic numerical model. The model combines the river hydro and morpho-dynamics computer models TELEMAC-2D and GAIA of the open source TELEMAC-MASCARET for investigating flow and sediment transport in open channels at large temporal and spatial scales. The field surveys revealed that the riverbanks near the estuaries (about 50-80km from the river mouth) are alternately eroded and deposited; however, erosion is dominant (Fig. 1). Erosion takes place even in some vegetated areas. We also found that some aquaculture ponds had to leave redundant due to riverbank erosion that cut off some ponds (Fig. 1, left panel). The results show changes in riverbank position for the next 50 years within the study area due to riverbank migration, i.e., accretion and erosion. It also shows that the general patterns of erosion and deposition at the main rivers and channels are represented reasonably well when seasonal river discharge is used. The model has been calibrated and validated with the collected field data between 2014 and 2019. This research serves as a developed reference in predicting the riverbank instability numerically, as to be considered in decision support strategies of the river system.

Keywords. Mekong delta, Riverbank erosion, 2D numerical modeling

Hydropeaking process in Vu Gia Thu Bon River basin: Causes, consequences, and main driven

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Abstract. Quantifying river flow change is important to understand the impacts of hydropower generation to water resources. Energy demand fluctuates at sub-daily scales, which may cause changes in regulated river flow (e.g., hydropeaking) resulting in the decrease of water supply and the increase of salinity intrusion. In this study, we investigated the influence of increasing hydropower generation on hydropeaking for the Vu Gia Thu Bon (VGTB) River basin, Central Vietnam. We used the analytical method to quantify the difference of water level in daily scale including the reservoir operation. This study used hourly water level data between 2018 and 2022 from seven hydrological stations within the VGTB River basin. Our key findings indicated that hydropeaking is at high levels in the VGTB River and has seen an increase over the last decade, especially over the past few years.

Keywords. Hydropeaking, Reservoir, Water level, Salinity intrusion, Water supply, Vu Gia Thu Bon River

Reviewing on flood simulation using hydrological models

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Abstract. Since ancient times, people over the world have often faced the dangers caused by various types of natural disasters including floods. Along with the development of modern science and technology facilities, flood disaster events have been increasingly studied and modeled, thereby developing preparedness, minimization and early warning systems. In this paper, we evaluate the available recent research on flood simulation on river basins using hydrological models. We distinguish between studies focusing on flood flow simulations using (i) rainfall-runoff models, (ii) hydrological models combining hydraulic models, remote sensing images and (iii) the models take into account land use changes, climate change and the operation of hydropower dams in the basin. We discuss the differences in the model's inputs and the accuracy in flood flow simulation mentioned in the studies. This allows to clarify the influence of the model's inputs on the flood flow simulation results to improve the accuracy in process of flood flow simulation. We also emphasize the characteristics and scale of the simulated watershed. The purpose of this assessment is to find out limitations in existing flood simulation methods to improve not only methodologies but also network design and monitoring system in order to increase the simulation accuracy and especially in flood forecasting to minimize flood risks and optimize the use of water resources in the basin.

Keywords. Flood simulation, hydrological models, accuracy, watershed

Monitoring the shoreline change in the coastal area of Da Nang City, Vietnam using time-series satellite imageries and Google Earth Engine platform

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Abstract. Shorelines are sensitive and vulnerable to human activities including urbanization, land reclamation and sediment loading. The deterioration of coastal ecosystems brought on by human activity may be reflected in shoreline changes. Therefore, it is important to understand shoreline dynamics. A significant source for analyzing changes in coastal ecosystems is earth observation data, such as multitemporal satellite imageries. In this research, we used Google Earth Engine (GEE) to monitor and map historical shoreline dynamics in the coastal zone of Da Nang City which is currently an attractive tourism destination of Viet Nam. Landsat imagery from 1986 to 2022 was processed in Google Earth Engine to calculate the MNDWI. Subsequently, applying a thresholding method, we have determined the water bodies that extracted the shoreline by different times. The change detection method in remote sensing has been employed to evaluate the shoreline dynamics in Da Nang coastal area. The results indicate that in the study area, the shoreline has moved by more than 5 km in the last decades, accounting for approximately 500 km² of land accretion. The proposed methodology can be applied to other coastal zones in various regions and scaled up to larger areas.

Keywords. Google Earth Engine, remote sensing, shoreline dynamics, Da Nang city

Evaluation of urbanization and climate change on urban water drainage system in central of Vietnam

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Abstract. Urban flooding is one of the significant issues that many cities are dealing with. Upgrading of the drainage systems is a common measure that is often used to address the risk of flooding. However, due to the effects of climate change, global sea levels are rising and extreme rainfall is increasing in both frequency and intensity. These has affected the flow, resulting in flooding in many cities worldwide. Among the types of models, the storm water management model (SWMM) is chosen for this research because it is widely accepted in academic and engineering communities. This research assessed the impacts of urbanization on the formulation of the flow at an urban catchment in An Ha, Tam Ky, Quang Nam. The results showed that urbanization contributes to reduce the flow loss through infiltration into the ground. When the degree of urbanization increases by more than 70%, the efficiency of flow reduction decreases rapidly, and the effects of urbanization are clearer for long rain duration.

Keywords. LID, urban flooding, urbanization, Tam Ky, storm water management

Comparison of 2D and 3D modelling for T-junction channel with different turbulence model

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Short abstract. The modelling of water flow at a T-junction is challenging due to complex fluid dynamics behavior. The flow mechanisms and dynamics need to be quantified before they can be used for river analysis such as riverbed scouring, riverbank erosion and water overtopping at the T-junction. This paper presents some validation and verification results of 2D and 3D modelling of the T-junction then compared with previous experimental works. The 2D simulation used the Menter's Shear Stress Transport $k-\omega$ (SST) and Low Reynolds $k-\varepsilon$ (LRE) turbulence models which solved by finite element method (FEM) using COMSOL Multiphysics. The 3D simulation used the Re-Normalization Group (RNG) turbulence model solved by finite volume technique (FVM) through FLOW-3D. The 2D simulation result was validated and verified using separation length (SL) that occurred at the branch channel of the T-junction. The results of 3D simulation were validated and proved the 3D RNG turbulence model can replicate the previous experimental result in term of discharge ratio (Q_r) which is the ratio of discharge in the branch to the upstream discharge with minimal difference from experimental work. The 2D SST turbulence model shows better result compared to the 3D RNG simulation and experimental data. The dynamics behavior of the water in term of pressure and velocity of the T-junction were discussed. The study shows that 2D turbulence model is sufficient for riverbank and river details analysis with some limitations.

Keywords. Turbulence modelling, RNG, SST, Low Reynolds $k-\varepsilon$, T-junction

Sediment Nutrient Fluxes and Links to Harmful Algal Blooms in a Eutrophic Lake using Diagenetic Modeling

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Abstract. In this study, we investigated a linkage between sediment diagenesis and harmful algal blooms in the Bay of Quinte, an embayment of Lake Ontario, Canada. Although a strong decline of external P loading to the Bay of Quinte during last decades, it still experiences harmful cyanobacterial algal blooms, which were hypothesized to be connected to nutrient loading from sediments. However, the linking sediment diagenesis with harmful algal blooms remain largely unknown. Our modelling framework integrated physical and biogeochemical processes at the sediment water interface (SWI) and incorporated dynamic boundary conditions, such as oxygen, soluble reactive phosphorus concentrations and organic matter sedimentation at the SWI. In the model, total P was divided into adsorbed, redox-sensitive, organic, aluminum-bound, and apatite forms. In this study, the Aquasim model was used and applied to link sediment diagenesis with harmful algal blooms of a eutrophic system, the Bay of Quinte, Canada. Our sediment diagenesis modelling results show that P burial efficiency critically increased after the period of external P loading reduction in 1970s corresponding to the decrease in total P, chlorophyll and most major phytoplankton groups in the water column.

Keywords. Phosphorus release, phosphorus burial efficiency, sediments, diagenetic modelling

Riverbank erosion assessment using Mike 21C modeling in Vu Gia – Thu Bon river (Quang Nam provincial region)

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Abstract. The riverbank erosion-accretion is mainly a physical process of river dynamics, reflecting the correlation between the flow and the channel, linked to the sediment balancy. Prediction of riverbank erosion-accretion plays crucial role for localy riverbank social economic development as well as for whole region. This study presents the results of Mike models (Mike11RR, HD, ST and Mike 21C) application to simulate the riverbed evolution (erosion, accretion). Compared with realistic changes, the results showed that the ability of simulation modelling is acceptable for Vu Gia – Thu Bon River basin. The riverbed change prediction according to the scenario of development and real-time approaches was calculated with updating boundary conditions of rain and erosion. From the simulation results, a map of the erosion risk was built to help risk management authorities and communities in riverbank erosion disasters proactive responding.

Keywords. Riverbank erosion, MIKE 21C, MIKE 21C, Vu Gia – Thu Bon

Overview of reservoir sedimentation in Batu Dam, Selangor, Malaysia

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Abstract. Reservoir sedimentation reduces storage capacity and shortens the lifespan of the dams. This paper seeks to the potential risk of reservoir sedimentation in Batu Dam, Malaysia. It is based on literature and findings from related studies on the sedimentation of the Batu Dam reservoir. Based on the feasibility study in 1980, the allowable annual sediment trapped was 40,000 m³/year as designed. Sediment accumulation for 50-year and 100-year sediment analysis is 1.85 m³ x 10⁶ and 3.70 m³ x 10⁶ respectively. According to the bathymetric survey in 2013, sedimentation occurs upstream of Batu Dam. Followed by the Formal Safety Inspection in 2015 reported that sedimentation was trapped at the lowest screen of the intake tower. It is proven by a previous sampling study in 2016 that most of the sedimentation categories as course material accumulated at the river mouth of Batu River upstream of the reservoir. Historical satellite images also capture the increase of area by sedimentation. An earlier remote sensing study in 2018 reported that sediment volume from 1987 until 2017 was about 7.31 million m³. Although this dam reservoir is designed to accommodate a certain amount of sedimentation, it is essential to keep monitoring sedimentation to manage a sustainable reservoir. The overall findings of this paper can assist in making better decisions for reservoir management.

Keywords. reservoir sedimentation, bathymetric survey, sediment sampling, satellite image, Batu Dam

Dynamic of Salinity Intrusion in Dinh An and Tran De Branches of Mekong estuaries

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Abstract. The increase of salt intrusion in recent years in the DinhAn and TranDe branches two of seven estuaries of the Mekong estuaries, has threatened the freshwater supply in the coastal regions, of Tra Vinh province. Combining the field survey and numerical modelling to investigate the salt transport mechanisms and the response of salt intrusion to changes in river discharge and tidal mixing have been conducted. The results of this research in the daily tidal cycle are that maximum salinity concentration (S_{max}) occurs at the bottom and later maximum water level from 1 to 2 hours. While S_{max} in the fortnight cycle appears during the transition period from neap tide to spring tide. The response of the salinity intrusion mechanism to the tidal velocity change is less than the river flow. However, when river flow increases, the impact of tidal velocity increases and the phase lag of response time decreases. The asymmetries of salt intrusion responding to increasing and decreasing river flow or tidal velocity are observed in the estuary.

Keywords. Salinity intrusion, Mekong estuary, tidal regime, tidal velocity

2nd Session on Hydrological Modelling and Sediment Management – B

Impacts of Reservoirs on Sediment concentration in the transboundary Srepok River Basin, Vietnam

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Abstract. In the Upper Srepok River Basin (USRB), one of the major tributaries with four cascade reservoirs already in place that may have negative effects on the downstream ecosystems, particularly the world's rice bowl in the Mekong Delta and the world's most productive inland fisheries in the Tonle Sap Lake, a process-based hydrological model was established. Changes in simulated streamflow and suspended sediment concentration (SSC) can therefore be linked to modifications in reservoir operations by maintaining the same climatic conditions, altering topographic factors associated to reservoirs, and introducing a reservoir management module. Both the annual and seasonal periods saw a sharp decline in the average and peak SSC. Sediment loads at the Ban Don station were 15% (140 000 tons/year) lower than they were before the dam was built.

Keywords. Srepok, HYPE, reservoirs, suspended sediment concentration

Integrated flood and sediment management in river basins for sustainable development: The case of Cagayan River Basin

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Abstract. Climate change threatens the world with disastrous floods and droughts, with Japan, Vietnam, and the Philippines among the worst-affected countries. This management paper highlights collaboration with Japanese and Vietnamese universities in implementing the international project “Integrated Flood and Sediment Management in River Basins for Sustainable”. Kyoto University transferred its technologies on flood and sediment management to Isabela State University and Thuyloi University thru trainings. The impacts of climate change and human interventions were assessed in the Vu Gia-Thu Bon River basin (Vietnam) and Cagayan River basin (Philippines). Bathymetry survey in the Magat dam showed reduced capacity of the reservoir due to sedimentations. Hence, funding for the dredging of the Magat dam was secured. Also, it was projected that climate change and landuse changes will significantly reduce water resources during dry years leading to droughts, and will abruptly increase during wet years leading to flooding. The rainfall-runoff-inundation model was locally optimized as a decision support tool for flood inundation forecast and upgrade dam discharge protocol during extreme rainfall events. The International Association on Climate Change Adaptation and Disaster Risk Reduction Management was created and registered as a science- government-community association to address Integrated Flood and Sediment management in river basins.

Keywords. Flood and sediment management, river basins

A conceptual approach to study influences of river sand mining on the depth-averaged velocity in vegetated compound channels

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Abstract. In the Mekong Delta, riverbed sand and gravel are usually over-extracted due to the increasing demand for materials for the construction industry. As a result, the river bed is often deeper, about two to three meters. Numerous studies have been published focusing on the morphological response induced by river sand mining in the short and long term. Nevertheless, the impact of elevation loss on the hydrodynamic processes in the mixing layer of compound channels at the reach scale is unclear, especially during the flooding stage. In order to obtain more insight, a schematised model of a vegetated compound channel in the Tieu Estuary was constructed in Delft3D. Different riverbed elevations were considered together with different vegetation densities on the floodplain. The numerical results reveal a significant modification of the outer layer in the mixing layer due to river sand mining, which may create unfavorable conditions for the lateral exchange of nutrients and sediment between the floodplain region and the main open channel.

Keywords. Sand mining, compound channel, vegetation, hydrodynamic, numerical model, mixing layer

Optimization of Magat dam operation rule for flood risk management in the Cagayan river basin

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Abstract. The Philippines has experienced several intense and devastating typhoons imposing significant threats to human lives and urban development. Therefore, this study aims to understand the flood characteristics by simulating the extreme Typhoon Ulysses at the Cagayan River, focusing on the Magat dam. Several scenarios have been conducted, including an assessment of the contribution of each sub-catchment and dam operations during the typhoon and an examination of additional proposed dams at the other sub-catchment. Rainfall-Runoff Inundation Model (RRI) was used and examined with four scenarios: a model without a dam, a constant discharge model and a constant rate discharge model for the operation of the Magat dam, and a case where the Magat dam and a new additional dam were installed. We found that some sub-basins had higher runoff than others. As for the operation of the Magat dam, the sedimentation countermeasures and pre-release of the Magat dam have flood control effects, but they are insufficient. It is expected that a proposed dam at the Cagayan Segment 1 could improve the flood risk in the downstream regions. Further scenarios considering the ensembled Rainfall data are needed to enhance dam operations and control flood impacts.

Keywords. Cagayan River Basin, Magat dam, dam operation, RRI model

Magat Dam science-based initiatives for long-term flood and sediment management

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Abstract. Addressing sedimentation problems in dam reservoirs is a process that involves identifying its sources and application of different techniques to monitor and reduce the further accumulation of sediment yield. This paper explains the results of the initiatives and collaborative efforts to focus on the issue of sedimentation in the Magat Dam reservoir. Recent 2021 bathymetric survey revealed that there is a reduction in the storage capacity by 65.34 MCM. From the turbidity measurements, results showed an average volume of 202,187.90 m³ of sediments for May. Structural and nonstructural ways to alleviate the impacts of sedimentation was done through the construction of sediment catchment structures and raising awareness on the importance of watershed resources through community extension seminar.

Keywords. Reservoir, sedimentation, techniques

3rd Session on Artificial Intelligence for Hydrological Application

Water level prediction model of Kien Giang river based on regression techniques

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Abstract. Model accuracy and running speed are the two key issues for flood warnings in rivers. Traditional hydrodynamic models, which have a rigorous physical mechanism for flood routine, have been widely adopted for water level prediction in the river, lake, and urban areas. However, requiring various types of data, some expertise and experience with models and intensive computation time limits short-term or real-time prediction of the traditional models. To achieve a real-time prediction for the water level, a new framework based on a machine learning method was proposed in this paper. We develop a water level prediction model using various machine learning models such as linear regression (LR), support vector regression (SVR), random forest regression (RFR), multilayer perceptron regression (MLPR), and light gradient boosting machine regression (LGBMR). The models compared to predict the hourly water levels in Kien Giang station of Kien Giang river based on collected data of 2012, and 2020. Three evaluation criteria, i.e., R², MAE, and RMSE, were employed to examine the reliability of the proposed models with others. The results show that the LR model outperforms the SVR, RFR, MLPR, and LGBMR models.

Keywords. LGBMR, linear regression, machine learning, MLPR, SVR, RFR, water level

Water level prediction of Kien Giang river using deep learning models

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Abstract. Time-series prediction of a river stage during natural disasters (such as typhoons and storms) is crucial for both flood control and flood disaster prevention. Data-driven models using deep learning (DL) techniques have proven to be an attractive and effective approach for water level prediction. This paper proposes a novel data-driven approach using deep learning network structures of Gated Recurrent Unit (GRU), Long Short-Term Memory (LSTM), and Bidirectional Long-Short Term Memory (Bi-LSTM). The models were implemented and validated based on an experimental dataset including observed data of hourly rainfall and water level at several meteorological and hydrological stations along the Kien Giang river. Two time leads scenarios of one and three hours were established to compare the prediction capability of three proposed models for the water level at Le Thuy station. Three evaluation metrics, i.e. R², MAE, and RMSE, are used to evaluate DL models. The results reveal that the LSTM model overperformed the Bi-LSTM and GRU models with the values of three metrics are 0,98; 0,068; 0,096 respectively.

Keywords. Bi-LSTM, Deep learning, GRU, LSTM, Le Thuy, Water level prediction

A real-time flood forecasting hybrid machine learning hydrological model for Krong H'nang hydropower reservoir

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Abstract. Flood forecasting is critical for mitigating flood damage and ensuring a safe operation of hydroelectric power plants and reservoirs. The authors introduce a hybrid hydrological model based on the combination of the HEC-HMS hydrological model and an Encoder-Decoder-Long Short-Term Memory network in this study to enhance the accuracy of a real-time flood forecasting. The proposed hybrid model has been applied to the Krong H'nang hydropower reservoir. The observed data from 33 floods monitored between 2016 and 2021 are used to calibrate, validate, and test the hybrid model. Results show that the HEC-HMS-ANN hybrid model significantly improves the forecast quality, especially for long forecasting time steps. The KGE efficiency index, for example, increased from $\Delta KGE = 16\%$ at time $t + 1$ to $\Delta KGE = 69\%$ at time $t + 6$ hours, similar to other indicators (such as peak error and volume error). The computer program developed for this study is being used at the KrongHnang hydropower to aid in reservoir planning, flood control, and water resource efficiency.

Keywords. Hydrological hybrid model, HEC-HMS, machine learning, KrongH'nang, real-time flood forecasting

Machine Learning Techniques and hydrological Modeling for Flood Susceptibility and Inundation Mapping: Case study VGTB River Basin, Vietnam

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Abstract. Vietnam has experienced many natural disasters, particularly typhoons. This study aims to examine three machine learning (ML) approaches—random forest (RF), LightGBM, and CatBoost—for flooding susceptibility maps (FSMs) in the Vu Gia-Thu Bon (VGTB) River Basin of Vietnam. The results of ML are compared with those of the rainfall–runoff model. Ten independent factors that influence the FSMs in the study area, namely, aspect, rainfall, curvature, DEM, horizontal distance from the river, geology, hillshade, land use, slope, and stream power index, are assessed. An inventory map that includes approximately 850 flooding sites is considered based on several post-flood surveys. The inventory dataset is randomly divided into two sets: training (70%), and testing (30%). The AUC- ROC results are 97.9%, 99.5%, 99.5% for CatBoost, LightGBM, and RF, respectively. The FSMs

developed by the ML methods show good agreement in terms of extension with flood inundation maps developed using the rainfall-runoff model. The FSMs show that downstream areas (both urbanized and agricultural) are under “high” and “very high” levels of susceptibility. The developed FSMs for such typhoon-prone regions can be used by decision-makers and planners in Vietnam to propose effective mitigation measures for community resilience and development.

Keywords. Machine learning, random forest, LightGBM, CatBoost, flood susceptibility mapping, rainfall-runoff inundation model

4th Session on Flood Risk Assessment

Urban flood forecasting based on hydraulic model by coupling of MIKE Flood and MIKE Urban: A case study of Tam Ky city, Vietnam

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Abstract. Tam Ky city is located downstream of Ban Thach and Tam Ky rivers in central Vietnam. According to annual statistics, this area is affected by heavy rains from tropical storms, so flooding is quite common here. This study establishes a flood forecasting model for Tam Ky city based on forecasted rainfall data and tidal level. A flood forecasting model is based on a proceeding of rainfall-runoff and is connected between the river basin and the city. The parameters of the flood forecasting model are calibrated and verified for floods that have occurred on rivers as well as in urban areas. An experimental flood forecast for Typhoon Nuru has just occurred on September 28, 2022. The forecast results of location and depth flooding in the city reflect the reality very well.

Keywords. MIKE Flood, MIKE Urban, Tam Ky City.

Flood modelling in the Ba River basin using a coupled hydrodynamic model- MIKE FLOOD

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Abstract. The problem of flooding in the Central Vietnam in general and the lower Ba River in particular is one of the natural disasters that frequently threatens people's lives and socio-economic development in the region. Especially, climate change is becoming ever more prominent and hotter, making extreme natural disasters more unusual and unpredictable. Many methods have been applied and shown to be effective in calculating floods. Under the development of science and technology, many hydrodynamic models were developed, and they have become speedy in the era of competitive computer industry leading to parallel computation. In this study, the MIKE-FLOOD model - a model that connects a 1-dimensional (1-D) MIKE 11 Hydrodynamics (HD) model with a 2-dimensional (2-D) MIKE 21 HD model was used to set up, calculated for 3 floods: (1) flood in October 1993, (2) flood in November 2003, (3) flood in November 2007, these are floods with frequency large and relatively large floods, especially the October 1993 flood is considered a historic flood in the region. The model testing correction indexes such as flood peak error (%), Nash index, correlation index R², are in good range and reliable enough to simulate large and relatively large floods for the area. The results of calculation and analysis of the flooded area compared with the inundation time of the October 1993 flood, show that the flood rises quickly and recedes quickly. When the flood water level reaches the maximum value, the total area affected by inundation corresponding to the flood water level is 22,600 hectares, accounting for 52% of the natural area, up to 16,500 hectares are flooded deeper than 1 meter, 11,000 hectares are flooded deeper 2 meters, 7,000 hectares were flooded more than 3 meters deep, 4,200 hectares were flooded more than 4 meters deep and the area flooded more than 5 meters deep was 2,200 hectares. The 2003 flood and the 2007 flood are two frequent floods in the basin, with a frequency of 20%, the flooded area when H max occurs at points in the study area is not much different compared with the exceptionally large flood of 1993 with a frequency of 5%, differing only in the value of each point. Especially in the center of Tuy Hoa city, the flooded area at the time of H max is almost 100%.

With the set of parameters set up in this paper, it gives us relatively accurate results in terms of quantity, type of flood and time of occurrence. Therefore, it can be used to simulate and predict floods for the Ba River downstream.

Key words. Flooding, coupled hydrodynamic model, MikeFlood model, Ba River basin

Study on flood mitigation operation of cascading dams, including hydropower dams in Ohi river

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Abstract. Dam pre-release is an effective measure against large-scale floods, whereas its implementation period is limited. In addition, there are a few considerations of pre-release in cascading dams, including hydropower dams. This study investigated the effect on the maximum discharge of each dam as the flood control effects and the discharge loss of hydropower dams, which directly connect to hydropower generation, by changing the start time and target water level of pre-release in cascading dams. By advancing the start time and increasing the target water level drawdown, the pre-release effects on flood control and water utilization have increased.

Keywords. Pre-release, cascading dams, hydropower, RRI model

Flood Vulnerability Indicators of Transportation System Concerning Climate Change

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Abstract. Transportation moves people and goods to different neighborhoods, cities, states, and countries. Transportation systems have included the concept of vulnerability, which has piqued the interest of academics in numerous disciplines of transportation. This is intended to increase the efficiency of transportation systems and mitigate the effects of disruptions. However, climate change is likely to impair transportation infrastructure by increasing temperatures, causing more severe storms and flooding, and increasing storm surges, compromising the reliability and capacity of transportation systems. Past works relating to transportation vulnerability had focused on different elements of vulnerability indicators and they have developed a more comprehensive concept. As a result, this paper offers a comprehensive review of vulnerability indicators concerning climate change. The primary focus of the study is to explore the flood vulnerability indicators considering the tropical climate in Malaysia. Based on this, prior research on transportation system vulnerabilities is examined in order to define the criteria required to assess transportation system vulnerability as well as the future directions of transportation vulnerability assessment.

Keywords. Climate Change, Flood, Indicator, Transportation System, Vulnerability

Stakeholders forum on integrated flood risk management in Cagayan River Basin: Basis in writing policy recommendations

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Abstract. The stakeholders forum aimed to enhance the capacities of policymakers, managers, and practitioners of river basin organizations on flood management through knowledge sharing of new approaches, techniques, methodologies, and good practices from partners here and abroad to help achieve effective implementation of integrated flood risk management as a component of integrated water resources management. Considering the designed series of activities, the forum highlighted the partnership of the Japan Water Agency and the Cagayan River Basin Management Council, a multipartite information exchange among the Philippine government agencies' dignitaries, political leaders and legislators, and Japanese stakeholders, and the update reports conveyed by numerous Philippine government agencies as well as their collaborative workshop engagement to scale up international community linkages. It also underscored the inauguration of the International Organization on Climate Change Adaptation and Disaster Risk Reduction Management Office, stakeholders' collaboration for technology transfer and knowledge-sharing activities at NIA stations, and the newly forged partnership between JWA and City of Santiago to promote UN-SDG 6 and water security. Thus, the forum served as a channel that bridged what the government agencies and organizations know about flood and sedimentation management and what the community partners need to understand to revitalize science-community-government-academe collaboration.

Keywords. knowledge sharing, technology transfer, water security, integrated water resources management, flood and sedimentation management

Development of a localized integrated disaster risk index – A Malaysia case study of Langat River Basin

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Abstract. Multiple disasters in Malaysia are observed to occur more frequently. This is due to impact of urbanization and climate change. Flood, landslide, debris flow and earthquakes are among distinct natural disaster seems to have great impact to the community. When it comes to community resilience, multi-vulnerability assessment is needed for a proper disaster management strategy. The index was developed by expanding on the multi-hazard spatial overlapping and Methods for the Improvement of Vulnerability Assessment in Europe (MOVE) theoretical framework. Two common hazards in Malaysia: floods and landslides were combined for the multi-hazard assessment. Multidimensional vulnerability combined six dimensions: social, economic, physical, institutional, environmental and cultural. A spatial vulnerability assessment is presented by mapping the risk val. The findings indicate that of the total areas in Langat River Basin, 14% has very high risk in which are urban areas. A validation of the index model was able to be done when a disastrous flood in December 2021 occurred at Langat River Basin. Assessment from the disaster impact data shows that one of the vulnerability dimensions which is areas with high institutional vulnerability were well correlated to the poor coordination or late emergency aid during the disaster.

Keywords. Multi-hazard, multi-vulnerability, disaster risk, Risk map

Mapping Open Fire Susceptibility and Nearest Water Resources For Fire Fighting -A Case Study in Johor Malaysia

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Abstract. Open fire releases toxic gasses and pollutant to air and can be destructive to the ecological, environmental and human infrastructure. Different methods and techniques for open fire susceptibility mapping are introduced according to the literature and can be classified into three groups: Probabilistic, statistical, and machine learning methods. In this research, we utilized the Random Forest (RF) machine learning approach for identifying the role of climatic and anthropogenic factors in influencing fire occurrence probability and mapping the open fire susceptibility for Johor State: Malaysia. A geo-database was established with 1726 Open fire sample locations and 12 predictor variables in total. Factor importance analysis was performed to identify the important factors of the occurrence of open fire in Johor state. The results show that the most important factor in the johor state region is distance to peatland. Additionally mean maximum temperature and distance to residential area are relatively important to open fire in Johor state. The model performance was evaluated using the receiver operating characteristic (ROC) curve method with AUC (Area under curve) value 0.86. The values of AUC using the best models are greater than 0.8, demonstrating that the model's predictive abilities are acceptable. The susceptible map can support future efforts in battling open fire and help local authorities in emergency planning. River and water body map overlayed on open fire map to calculate the distance of susceptible area to the nearest water resources.

Keyword. Open fire, susceptibility, random forest, fire fighting

Response of long-term hydrological to land use/land cover change in Vu Gia Thu Bon River basin

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Abstract. The Vu Gia Thu Bon River basin, Vietnam, is an important watershed supporting drinking water, and agricultural activities in Central Vietnam. However, the potential hydrological impacts of LULC change in recent decades, are not quantified. Therefore, assessing long-term hydrological impacts of land use/land cover (LULC) change is of critical importance for land use planning and water resource management. This work would assess the long-term impacts of LULC change on streamflow and suspended sediment concentration. LULC records are collected annually from Launch Regional Land Cover Monitoring System (RLCMS) from SERVIR–Mekong between 1987 – 2018. Our key findings indicate interesting results, in which the simulated streamflow and sediment loads within this river basin have decreased due to deforestation. Thus, these findings would serve as a scientific basis for future management plans of stakeholders and decision-makers regarding water resources management.

Keywords. Land use/land cover (LULC) change, streamflow, suspended sediment concentration, vu gia thu bon, vietnam

Modeling the urban flood during the heavy rain in October 2022 for Ngu Hanh Son District, Da Nang City using SWMM model

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Abstract. Urban flooding is one of the challenges by large cities in Vietnam, especially in Ha Noi, Ho Chi Minh, and Da Nang cities which are the largest cities in the country. The process of urbanization under the context of climate change is one of the causes of urban flooding in recent years. Therefore, the simulations of urban flood and drainage systems in typical rain are important to build the warning map of the risk to the local community. The main objective of this study is to use GIS modeling to warn of the risk of local flooding in some routes in Ngu Hanh Son district, Da Nang City during the heavy rain in October 2022 which is considered the most severe rainfall in the past 20 years. The main purpose of the simulation of urban drainage in Ngu Hanh Son through the October 2022 rain is to determine a reasonable set of hydrological- hydraulic parameters for the construction of hazard warning maps for flooding due to rain. Within the scope of the paper, we will present the results of the urban drainage simulation for Ngu Hanh Son district by using the Storm Water Management Model (SWMM) model with in- situ rainfall data on October 14th, 2022.

Keywords. Da Nang City, Ngu Hanh Son, urban flood, heavy rain, SWMM

Nonparametric estimation approach for evaluating the trend of hydro-meteorological factors in Lai Giang, Binh Dinh

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Abstract. With the purpose of analyzing trend variations of hydro-meteorological factors in Lai Giang catchment, as a basis for the planning as well as socio-economic development of the locality in the future, the research uses the nonparametric estimation method to evaluate the tendency of changes in rainfall, runoff and temperature at stations in the basin. Based on data of more than 40 years, from 1980 to 2020, hydro-meteorological factors are analyzed with different parameters, such as annual average, annual maximum, annual minimum, dry season average, and maximum daily rainfall, three-day maximum rainfall, etc. Research results show the change of factors in space as well as over time. At the same time, the study also builds up the trend equation of the research quantities, as a basis for future scenario assessment.

Keywords. Nonparametric estimation; rainfall; runoff, Mann-Kendall

Impacts of drought on water resources in Central Vietnam. A case study of Vu Gia Thu Bon River basin

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Abstract. Severe droughts cause substantial damage to different socio-economic sectors, and even Vietnam, which has abundant water resources, is not immune to their impacts. To assess the implications of a severe drought in Central Vietnam, we carried out a regional-scale drought impact analysis. We have assessed extreme to moderate drought events starting from 1980 to 2020 using the Standardized Runoff Index (SRI) drought classification. The runoff is collected from observation and the results of the Soil and Water Assessment Tool (SWAT) hydrological model. The results indicate that the long-lasting drought caused a significant decrease every year. Thus, we suggest that the resilience to droughts could be improved with region-specific drought management plans and by including droughts in existing regional preparedness exercises.

Keywords. Central Vietnam, drought, Standardized Runoff Index (SRI), SWAT

Quantification of GPM IMERG and SM2RAIN-ASCAT rainfall products over complex terrain under impacts of reservoirs. A case study for Srepok River basin

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Abstract. Precipitation has a direct link to the water cycle and remains the primary driver to study climatic extremes. The impact of precipitation on key variables such as soil moisture is complicated to observe in nature and is often poorly represented. In this work, we validate two precipitation products namely (i) the Global Precipitation Measurement mission (GPM) integrated Multi-satellite Retrievals (IMERG), (iii) SM2RAIN-Advanced SCATerometer (SM2RAIN-ASCAT over Asia). The IMERG precipitation product is derived from multi-satellite precipitation product (top-down approach) and the SM2RAINASCAT is derived from surface satellite soil moisture (bottom up approach). Our key findings indicate the superior performance by GPM IMERG product over the Srepok River basin, in which impacts of new- built reservoirs were also included.

Keywords. Precipitation, SM2RAIN-ASCAT, GPM IMERG, Srepok River basin, Vietnam

River System's Behavioral Changes in Response to Manmade disturbances

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Abstract: Modification of landscape directly implicate to the stream water quality by increasing the sediment and pollutants run off into river. The elevated terrestrial sediment deposition has impacted river morphologies, channel patterns, and affected its quality. This has emerged as a matter of concern in terms of water security and catastrophic flooding especially in developing nations. Thus, a better understanding of sediment dynamics and distribution is crucial to advance the knowledge of fluvial systems and its behavioural changes particularly in the tropics: a case study from Malaysia on the reconstruction of temporal sediment dynamics, identification of sediment sources, and quantification of the respective contributing sediment sources is presented, alongside with the impacts to river water quality. Storm events are one of the main causes of mobilization and transport of solutes into and within stream channels. The nonlinearity of solute transport during storm events is evident. Land-use and land cover changes related to timber harvesting and conversion into agricultural plantation under various national economic plans and initiatives have been recognised as a major driver of sediment yield and delivery in studied watersheds.

Keywords. Water quality index, sediment fingerprinting, multi proxy sediment, sedimentation

Analysis of spatial and temporal variation in rainfall trend of Vu Gia Thu Bon River Basin, Vietnam

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Abstract. This study examines rainfall spatial and temporal variation in the Vu Gia Thu Bon River basin from 1979 to 2021. The Mann-Kendall (MK) and Sen's Slope estimator test, which can determine rainfall variability and long-term monotonic trends, were utilized to analyze 16 rainfall stations that are distributed all over the river basin. The results showed that the pattern of annual rainfall was prevalent everywhere. Every location has a tendency to grow or to be insignificant. This pattern suggests that Vu Gia Thu Bon will have significantly more rainfall in the coming years. The examination of monthly rainfall yielded findings that 10 areas had noticeable rising tendencies. Trends in rainfall suggest that this area has seen climate change.

Keywords. Vu Gia Thu Bon River basin, rainfall, Mann-Kendall test, Sen's Slope

Spatio-temporal variability and trends of extreme rainfall and temperature events over Cagayan River Basin, Philippines

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Abstract. Extreme climate events, such as heavy rainfall, drought, flood, and heat waves, have become the most common natural disasters over the Cagayan River Basin. Addressing the consequences and the occurrence of these disasters has always a major challenge, due to increasing population and the impacts posed by extreme climate events. In order to help meet these challenges, this study has been undertaken considering the aim of evaluating of spatio-temporal variation of extreme climate events based on comprehensive assessment of extreme rainfall and temperature indices using long-term high-spatial-resolution climate data for worst-case (RCP8.5) climate change scenarios of MRI-AGCM3.2S data. The findings indicate an increased risk of extreme climate events such as extreme dry spells and extreme wet spells in future, which may lead to greater vulnerability to drought and flood over CRB. These findings would be a straightforward resource for addressing the high-risk zone and guiding disaster risk reduction authorities in making appropriate decisions for implementing adaptation strategies.

Keywords. Extreme Climate Events, flood risk, drought risk, climate change adaptation, spatio-temporal changes

Trends of low flow in the Vu Gia-Thu Bon River basin, Central Vietnam

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Abstract. Analysis of trends in low flow plays a significant role in water resource planning and operation. The main objective of this study is to examine the low flow trends as well as precipitation trends in the Vu Gia – Thu Bon during the period 1976 – 2014 non-parametric test Mann – Kendall. The analysis was carried out on monthly and annual time scales. Besides, the regime shift assessment was conducted to detect any abrupt change in the flow regimes. In addition, SPEI03 and SPEI06 were calculated in order to understand the drought situation in the same period. The results revealed that there is a significant upward linear trend in the annual precipitation by 17.03 mm/year between 1976 and 2014. However, the month-by-month analysis revealed that the increased precipitation primarily was during the rainy season. For the flows in Vu Gia and Thu Bon rivers, there are similar increasing trends in the discharges at the Thanh My station by approximately 1.617 m³/s and Nong Son station by 2.725 m³/s, respectively. Still, the increasing trends with the most significant ones being identified at seasonal rather than annual scale. Regarding the regime shifting, there were prominent alterations in some months during the dry season in 1999 which was recorded in February at Nong Son station (Thu Bon river) and in February, April, May, and July at Thanh My station (Vu Gia river). Additionally, the examination of drought identified a decline in drought occurrences' frequency, duration, and intensity for the period post-2000. These findings will contribute numerous values to improve the integrated water resource management in the region.

Keywords. Low flow, drought, Mann – Kendall test, Standardized Precipitation Evapotranspiration Index (SPEI)

5th Session on Remote Sensing and GIS for Flood and Water Security

Evaluation of water indices for dynamic monitoring reservoir surface water using Landsat 8 data

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Abstract. Consistent dynamic monitoring of surface water area is significantly essential for reservoirs operation and management. Threshold segmentation method is mostly used for surface water extraction by applying fixed water index thresholds, which can be incompatible for regions with distinct characteristics. This study aims to evaluate the most suitable thresholds for three widely used water indices, i.e. Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI) and Automated Water Extraction Index (AWEI) for detecting and extracting surface water of Phu Hoa reservoir in Quang Binh province from Landsat-8 imagery. Google Earth Engine platform is used to automatically collect low cloudiness scenes, compute three proposed indices, then detect and extract water surface using different threshold values. Accuracy evaluation of the extraction results is carried out by calculating Overall Accuracy (OA) and Kappa coefficient (kappa) based on observed water level and reservoir characteristics curve. The results show that the most effective thresholds for NDWI, MNDWI and AWEI are -0.4, -0.25 and -0.55; with OA and Kappa vary from 92÷96% and 0.84÷0.89 respectively. Chosen thresholds are then adopted for monitoring the dynamic of surface water of Phu Hoa reservoir over the period 2013-2021 that supports decision makers in process of reservoir operation and management.

Keywords. Landsat 8; Phu Hoa reservoir; Surface water extraction; Water indices

Impact of different types of vegetation in reducing roof runoff

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Abstract. Rapid development in urban area increased the flash flood occurrence. This is due to increasing of impervious surface in the urban area. Therefore, vegetated roof is introduced in order to reduce the peak discharge, velocity and quantity of the runoff generated during rainy season thus reducing flash flood occurrence. The objective of this study is to investigate the impact of different types of vegetation on roof runoff. Cow grass, carpet and pearl grass were selected to be installed on the roof. The vegetated roof was constructed in the laboratory and rainfall simulator was used in order to imitate the rainfall event. High intensity rainfall was implemented in this study. The results found that pearl grass was the best in reducing the volume of the roof runoff compared to cow and carpet grass.

Keywords. Flash flood, vegetated roof, roof runoff, peak discharge, pearl grass, cow grass, carpet grass

Impacts of anthropogenic activities on riverbed elevation. A case study in Central Vietnam

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Abstract. Anthropogenic activities such as dams and sand mining are considered as one of the main driving causes changes of in riverbed elevation in the Vu Gia Thu Bon (VGTB) River basin. Therefore, assessing the impact of human activities on riverbeds can provide scientific insight to understand the morphological change and complex hydrological as well as to develop strategies for VGTB river basin management and sustainability. In this study, the riverbed data (in 2010, 2015, 2018, and 2021) and sediment size (in 2021) were analyzed to further clarify the changes of dams upstream and sand mining. We find that the riverbed elevation changes from downstream dams on Vu Gia and Thu Bon Rivers by 68 km and 74 km, respectively. The riverbed changes are greatly concentrated in the sand mining sites. The water level was driven by riverbed incision, and this is likely one of the main causes of the enhanced salinity intrusion.

Keywords. Dams, sand mining, riverbed elevation, vu gia thu bon river

Livelihood resilience: salinity intrusion hazard assessment of and adaptation strategy for socio-economic development in Ben Tre Province

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Abstract. The impacts of climate change and human activities have caused several hydrology-related challenges, such as severe drought and salinity intrusion, in the Vietnamese Mekong Delta. The study attempts to assess livelihood resilience in the Ben Tre Province under the increasing frequency of drought and salinity intrusion and to correlate salinity intrusion with resilience level geographically in four dimensions: social (community-based); economic (finance-based); institutional (governance-based); and infrastructure (technical-based). These objectives were achieved by field surveys, questionnaires, and one-dimensional hydrodynamic modelling. The results show that total community resilience in Ben Tre is a function of its subcomponents in social, economic, infrastructural, and institutional dimensions. The contribution of each subcomponent to the aggregated community resilience is relatively similar, indicating that it might necessitate a uniform change of all subcomponents to change the tendency of the overall resilience. Both overall and subcomponent resilience is inversely proportional to salinity concentration. The governance capacity in geographically challenged areas is less likely to receive the benefits of aid and local assistance, thus reducing their resilience and increasing their vulnerability. To improve the livelihood resilience for sustainable development in Ben Tre, not only technical measures but also governance capacity, institutional coordination, and community media need to be integrated.

Keywords. Ben Tre, livelihood resilience, salinity intrusion

GIS-based flood susceptibility mapping using AHP approach: A case study of Kien Giang river basin, Quang Binh province

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Abstract. Flood is the most devastating and unpredictable risk in Vietnam. As flood defence measures are becoming increasingly popular, researches on comprehensive flood assessment and management are still limited at local and national levels. This paper focuses on flood assessment in the Kien Giang river basin, which suffers from particularly severe floods, using the combination between flood susceptibility mapping and Analytical Hierarchy Process (AHP). While susceptibility map provides holistic levels and extent of the flood-affected area, based on the main flood-causing criteria; the AHP technique give the pair-wise comparison matrix to calculate the factor weights. Flood-related factors include TWI, land use, land cover, elevation, slope, precipitation, NDVI were considered and defined as raster dataset with the resolution of 10m. The levels of flood susceptibility are classified into five classes, i.e. very low, low, moderate, high and very high. The results indicate that 35.2% of Kien Giang river basin is considered as high and very high level of susceptibility while moderate susceptibility accounts for 40.5%. The AHP results also show that elevation and precipitation influence the most to find areas susceptible to flooding. This research constitutes a qualitative and quantitative tool that can be widely applied to localities, therefore helps local authorities to mitigate damage caused by floods.

Keywords. Analytical Hierarchy Process, flood susceptibility, GIS, Kien Giang river basin

6th Session on Hydrological Modelling and Sediment Management - C

Hydrodynamic modelling of Magat dam and reservoir during extreme conditions using Telemac 2D

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Abstract. In the case of Magat dam and reservoir, the significant storage capacity loss will indefinitely affect the agricultural production under the areas serviced by the said reservoir. This is in addition to the communities that depend on the reservoir for their domestic uses. Based on the accumulated sediment volume for the past five (5) years, the remaining storage capacity for the Magat Reservoir is now at around 570 MCM, in contrast with its 1.08 BCM designed capacity. With these data, it is only expected to get worse if no effective sediment management is employed. A purely hydrodynamic modelling is performed on Magat reservoir to evaluate the ability of Telemac 2D in simulating the actual flow during extreme events. The hydrodynamic behavior in the reservoir level was accurately reproduced using Telemac 2D. This model was calibrated and validated using flow data during typhoons Rolly and Ulysses (November 2020) and Severe Tropical Storm Florita (August 2022). The simulated results showed that the applied model could precisely reproduce the outflow events. The hydrodynamic model is planned to be coupled with the sediment transport module “Gaia” to potentially understand the sediment transport dynamics of the Magat Dam and Reservoir.

Keywords. hydrodynamic modelling, Magat dam and reservoir, Telemac 2D

Evaluation of coastline change in Quang Nam under the influence of jetty construction

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Abstract. In recent years, coastal erosion and accretion have been observed and amplified along Quang Nam coast, which causes serious adverse impacts to inhabitants as well as rich ecological values along the coast. In the master plan for Cua Lo port, a jetty is constructed in the north of Cua Lo estuary to protect the harbor basin of the port from sediment deposition. In this study, the numerical model GENCADE is used to evaluate the changes of Quang Nam coastline, i.e. from Cua Dai estuary to Cua Lo estuary. Different values of model-specific parameters K1 and K2 have been examined to compare the calculated coastlines with the image-analyzed ones for evaluating the accuracy of the model. The results reveal that 0.4 and 0.2 are the optimal values for the study area's empirical coefficients K1 and K2. The well-validated model is then adopted to evaluate the coastline change under the influence of jetty construction. The GENCADE results indicate that after 10 years, 20 years and 50 years of operation, shoreline modifications reach a distance of 250 m, 360 m and 450 m toward the sea respectively. Finally, the length of the jetty will be proposed based on these accretion predictions.

Keywords. Cua Lo port, GENCADE, Quang Nam coastline, sediment transport, shoreline change

Evaluation of hydrodynamic and sediment transport under construction of Cua Lo's navigation channel

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Abstract. Cua Lo is one of the most potential areas for port economic development in Chu Lai Open Economic Zone, Quang Nam province. To protect navigation channel from sedimentation and waves, according to master plan, two jetties are constructed in the North and South Cua Lo by dredging and cutting through the sand spit in the North bank. Prediction the impacts of navigation channel construction and its protections on the hydrodynamic regime and deposition process plays an important role for the success of a port project. In this study, the numerical model Delft3D is developed to evaluate the morphodynamic change of Cua Lo, then calibrated and validated using the observed data in two survey campaigns in 2019. The simulation results reveal that, in the positions with the highest wave height, the construction has had a significant effect of reducing wave height, the reduction is about $0.8 \div 0.9$ m, equivalent to 50% compared to the absence of jetties during Northeast monsoon period and $1 \div 1.16$ m in adverse conditions, such as floods and storms. In addition, the structures have flood drainage effect with the reduction of maximum water level of $0.8 \div 1.2$ m in comparison to the current situation. Moreover, in terms of deposition process, for the area of the new navigation channel between the two jetties, the constructions have effectively reduced the fluctuation of accretion and erosion, about 2500m³/year.

Keywords. Cua Lo port, DELFT3D, hydrodynamics, sediment transport

Two-dimensional numerical models in simulating hydro-sediment-morphodynamics for the Vu Gia Thu Bon River basin

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Abstract. This study aims to establish a complete hydro-sediment-morphodynamics model (TELEMAC-2D + GAIA + NESTOR) and ensure the accuracy of the Vu Gia Thu Bon (VGTB) River basin located in Central Vietnam. The model has been calibrated and validated at six hydrological stations along the river system in 2019, 2020, 2021 and statistical indicators perform good results. The model is able to capture the peaks of water levels in all stations during flood events. The performance R^2 are 0.78, 0.81, 0.95, 0.94, 0.92, and 0.96 at Hoi Khach, Ai Nghia, Cam Le, Giao Thuy, Cau Lau, Hoi An. Similarly, NSE values range from 0.74 at Ai Nghia station to 0.94 at Hoi An station. Moreover, RMSE values vary from 0.041 m to 0.238 m. The simulation results of suspended sediment concentration also have good performance compared with data from turbidimeter and GoogleEarth Engine. The model has well simulated riverbed elevation changes from 2018 to 2021. The results of this study would serve as the primary reference for water resource and sediment management, flood control, hydropower development, and agricultural production. Meanwhile, it provides reliable research data and results for scientists, stakeholders, decision-makers, and local communities, to quickly adapt to climate change and ensure sustainable development for the VGTB River basin.

Keywords. Two-dimensional, hydro-sediment-morphodynamics model, TELEMAC-2D, GAIA, NESTOR, Vu Gia Thu Bon River

Assessment of salinity intrusion trends along main rivers and coastal zones in the Vietnamese Mekong Delta

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Abstract. Research on the vulnerability assessment of the Vietnamese Mekong Delta (VMD) is a long story due to the booming challenges of climate change, sea level rise, and salinity intrusion. Remarkably, the salinity intrusion level in this delta has peaked at the highest level in the 21st century, minimizing the available farming productivity and continuously reducing agriculture's economic benefits. Therefore, this research attempts to assess the salinity intrusion trends along main rivers (i.e., Tien, Hau, Co Chien, Ham Luong) and coastal zones (i.e., East and West Vietnam Seas) to understand spatiotemporal variations of salinity intrusion in the VMD. To this end, we analyzed daily salinity concentration at various monitoring stations for more than two decades using several statistical analyses for different indicators of salinity levels. We found that the maximum salinity concentration at Tran De in the Hau River and Vam Kenh in the Tien River (which are near the river mouths) statistically decreased by 0.45 and 0.2 mg/L/year ($p < 0.05$), respectively. At other stations near the river mouth, salinity concentration was relatively stable over the period analyzed. However, salinity concentration statistically increased at stations far upstream from river mouths. This indicates that upstream development, such as river damming and sand mining, is the driving force of the intensifying salinity intrusion in inland areas through morphological degradation.

Assessment of water scarcity under the impact of climate change in the downstream Vu Gia-Thu Bon river basin, Vietnam

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Abstract. The downstream Vu Gia-Thu Bon river basin supplies more than 90% of the water needed for home and industrial use in Da Nang. The water extraction point used to supply the Cau Do - Da Nang clean water factory has experienced an increase in salinization since 2012, which has had a significant influence on water use in the downstream area. The water at the Cau Do factory's extraction site has been salty for 119 days in the first half of 2019, necessitating additional pumps from the An Trach dam. The study used the following computation to get the water stress index (WSI) for 15 areas that make up the Vu Gia-Thu Bon river basin. In the assessment, the water demand for the ecosystem is also considered as a required amount of water in the basins. The MIKE SHE hydrological model with the full major processes in the hydrologic cycle including process models for evapotranspiration, overland flow, unsaturated runoff, groundwater flow, channel runoff and others are used to simulate river flows in the study area for the period of 1980– 2020 and to forecast for 2030. The study also found it important to distinguish subsurface from surface water when calculating the impact of freshwater extraction. The results show that: (1) Water shortages are more severe in the downstream regions than they are in the middle and upstream, particularly where water is being exploited for domestic and industrial use in Da Nang city. (2) Except for the times when the reservoirs release water, the majority of the WSI values between March and May 2020 are higher than 0.6, with a peak of a WSI of more than 3.4, signifying severe scarcity. The Quang Nam-Da Nang region's summer rainfall change in 2030 will drop from 1.9 to 2.1% under the B1 low emission scenario, and the region is likely to experience more severe and extreme droughts. In comparison to 2020, the WSI grew by two times. Water shortages are expected to start earlier and remain longer in 2030, lasting from the beginning of February through September. (3) To address issues with drought, water scarcity, and salinity prevention in the context of climate change and sea level rise, the region needs proactive, suitable adaptation and planning for water resource management. In the downstream region of the Vu Gia river, alternatives for a safe water supply have also been suggested by the research.

Keywords. Downstream Vu Gia – Thu Bon river basin, MIKE SHE model, Environmental Water Requirement, water stress index

Probable maximum precipitation estimates considering homogeneous regions of Malaysia

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Abstract. Probable maximum precipitation (PMP) values adopted using state boundaries had reported to increase due to substantial increase in atmospheric moisture content and consequent higher levels of moisture transport into storms. Homogeneous regions with similar rainfall characteristics are formed using L-moments method and adopted in the statistical PMP estimation for Malaysia. This research aims to assess the differences between the PMP values estimated using the extreme rainfall homogeneous regions compared to PMPs value estimated using conventional state-boundaries for 1-hour and 24-hour storm duration. The results were compared to projected rainfall from the Non-Hydrostatic Regional Climate Model (NHRCM). Results show that using rainfall data from 1969 to 2012, the PMP estimated using the homogeneous region have higher values compared to the PMP estimated using the state-boundaries. Moreover, the highest historical rainfall up to 2020 exceeds the PMP estimated using the state boundary but were not exceeded by the PMP estimated using the homogenous regions. The PMP estimated using the homogeneous region also have higher values than the highest projected rainfall obtained from NHRCM data (2079-2099).

Keywords. Extreme-rainfall, homogeneous regions, probable maximum precipitation

Climate change intensifies drought vulnerability of magat sub basin in the Philippines

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Abstract. This study was conducted to assess the socio-economic impacts of climate change on the vulnerability of a significant river basin in the Philippines, the Magat River Basin, to drought by considering agriculture as the major sector of focus. The results of this study imply that the current drought susceptibility of Magat Watershed is at 1.9 – 3.39 min-max scale or from low to above moderate, where the basin's Sensitivity and Exposure, account for 57% and 31% of the total vulnerability, respectively. And that the resulting adaptive capacity has a mitigating factor of only 12%, thereby construed to be very low. And is projected to increase in the future by up to 30% under climate change scenarios.

Keywords. Climate change, drought, GIS, indicator, Magat watershed, vulnerability



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