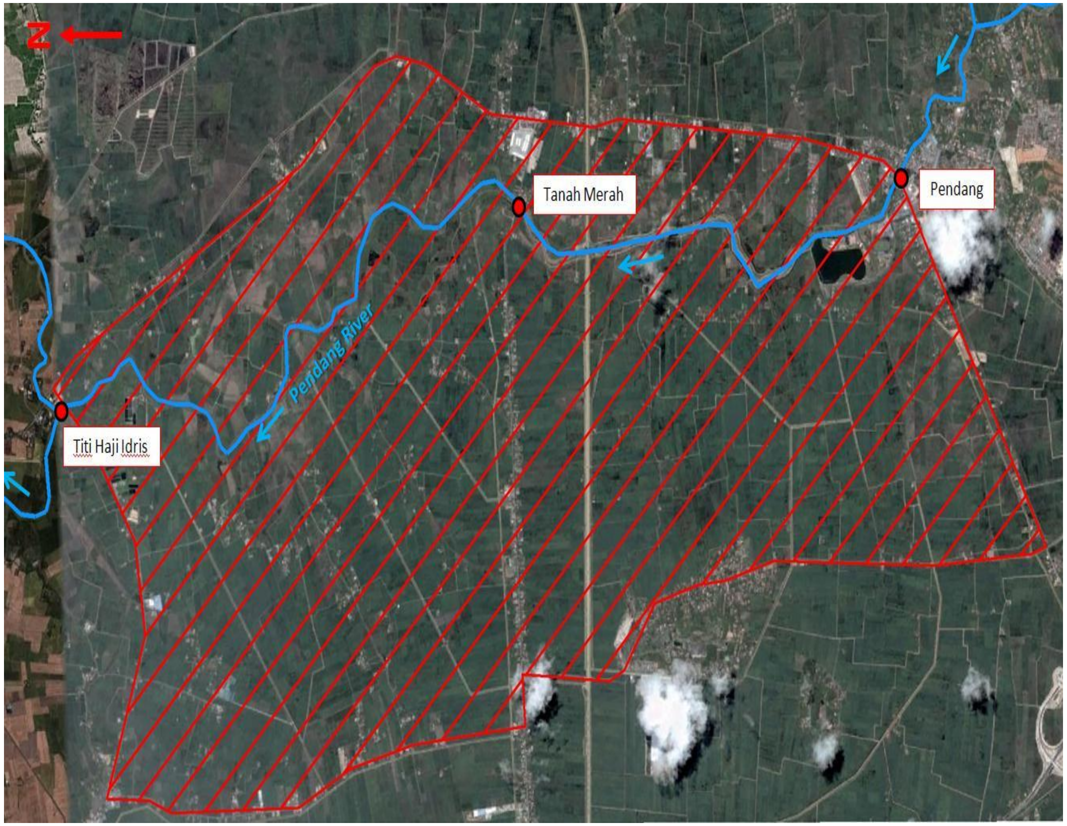
Case Study for Monetary Assessment of Flood Control and Sediment Control function of Paddy Fields in Muda Irrigation Scheme, Malaysia



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Presentation outlines

1. Introduction to INWEPF
2. Introduction to the case study
3. Methodology
4. Result and discussion
5. Conclusion

1.0 Introduction to INWEPF

INWEPF – International Network on Water and Ecosystem in Paddy Fields.

- **Established in order to address three challenges,**

1. **Food security and poverty alleviation**
2. **Sustainable water use**
3. **Partnership**

- **Member Country:**
  Japan, South Korea, China, Malaysia, Cambodia, Sri Langka, Nepal, Thailand, Indonesia, Vietnam, Myanmar, Philippines, Lao PDR, Bangladesh, Egypt, India and Pakistan
- **International Authority:**
  IWMI, FAO, MR, ICID, PAWEES and Others

- **Working Group 1 : Multiple roles of paddy fields, Lead by INWEPF Malaysia**

1.0 Introduction to INWEPF

ROLES OF PADDY FIELDS COVERS THE SOCIAL, ECONOMIC, ENVIRONMENT AND CULTURES OF THE COUNTRIES

1) Flood Control
2) Water quality improvement
3) Prevention of soil erosion
4) Recharge of groundwater
5) Conservation of biodiversity
6) Climatic mitigation
7) Food Security
8) Social economic improvement
9) Cultural, Tourism and Educational Aspect

1.0 Introduction to INWEPF

MULTIPLE ROLES:

MEMBER COUNTRY TASKS

INWEPF through its Working Group 1 has embarked in initiating pilot studies in member countries on multifunctional roles of paddy fields. Tasks were distributed among member countries.

1) **Flood Control – Malaysia, Thailand**
2) **Water quality improvement – Thailand, Egypt**
3) **Prevention of soil erosion – Malaysia**
4) **Recharge of groundwater – Sri Lanka, India, Bangladesh**
5) **Conservation of biodiversity – Philippines**
6) **Climatic mitigation - India**
7) **Food Security – Egypt, Indonesia**

International Network on Water & Ecosystem in Paddy Fields

INWEPF SYMPOSIUM 2015

Achieving the Goals of Food security

In Sustainable Paddy Water Ecosystems

INWEPF

3-5 November 2015

Colombo -SRI LANKA

Organized By

IWMI
International Water Management Institute

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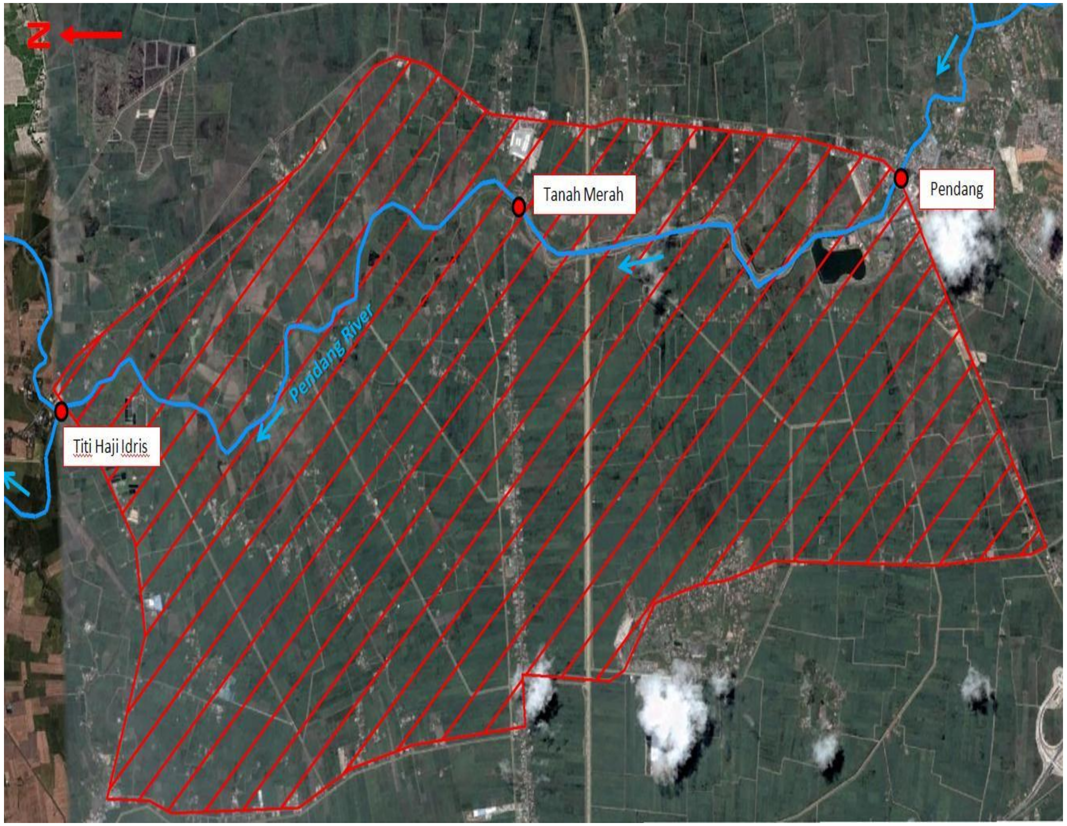

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2.0 Introduction to case study

EVALUATION AND MONETARY ASSESSMENT OF MULTIFUNCTIONAL ROLES OF PADDY FIELDS

1. INWEPF promotes the Evaluation and Monetary assessment of various roles and functions of paddy field and steps towards the enhancement those values
2. The best way to quantify intangible values is to equate them to dollars and cents. Through such assessment, it would be easier for parties to appreciate the values
3. During WWF 5, INWEPF published a preliminary monetary assessment of 3 functions for its member countries.
4. The three functions are flood prevention, ground water recharge and inhibiting soil erosion.
5. The values are as shown in the table.

Monetary value of Flood Prevention, Ground water recharge and soil erosion inhibiting of paddy fields in INWEPF Member Countries

Country	Area of Paddy	Annual Monetary Value				Rice production value
		Flood prevention	Groundwater recharge	Soil erosion inhibiting	Total	
	ha	Mill. USD	Mill. USD	Mill. USD	Mill. USD	Mill. USD
Japan	2,602,319	27,157	586	327	28,070	22,856
Bangladesh	10,780,000	199	8	38	246	5,725
Cambodia	2,414,500	46	5	17	68	879
China	29,116,000	812	3,111	45	3,969	27,467
Egypt	700,000	24	0.3	0	24	1,654
India	43,660,000	1,293	1,867	147	3,306	20,620
Indonesia	11,800,901	294	382	266	942	11,352
Korea	1,084,024	1,038	145	27	1,210	3,654
Laos	736,020	15	3	5	23	313
Malaysia	676,200	106	24	33	162	474
Myanmar	7,008,000	49	41	50	140	3,244
Nepal	1,453,000	34	12	8	53	614
Pakistan	2,621,400	53	1,494	0	1,547	1,776
Philippine	4,272,890	171	1,440	127	1,738	2,766
Sri Lanka	915,260	68	20	4	92	517
Thailand	10,224,966	1,240	65	164	1,469	4,980
Viet Nam	7,329,200	147	490	47	684	4,356
Total / Average	137,394,680	32,746	9,693	1,305	43,744	113,247

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2.0 Introduction to case study

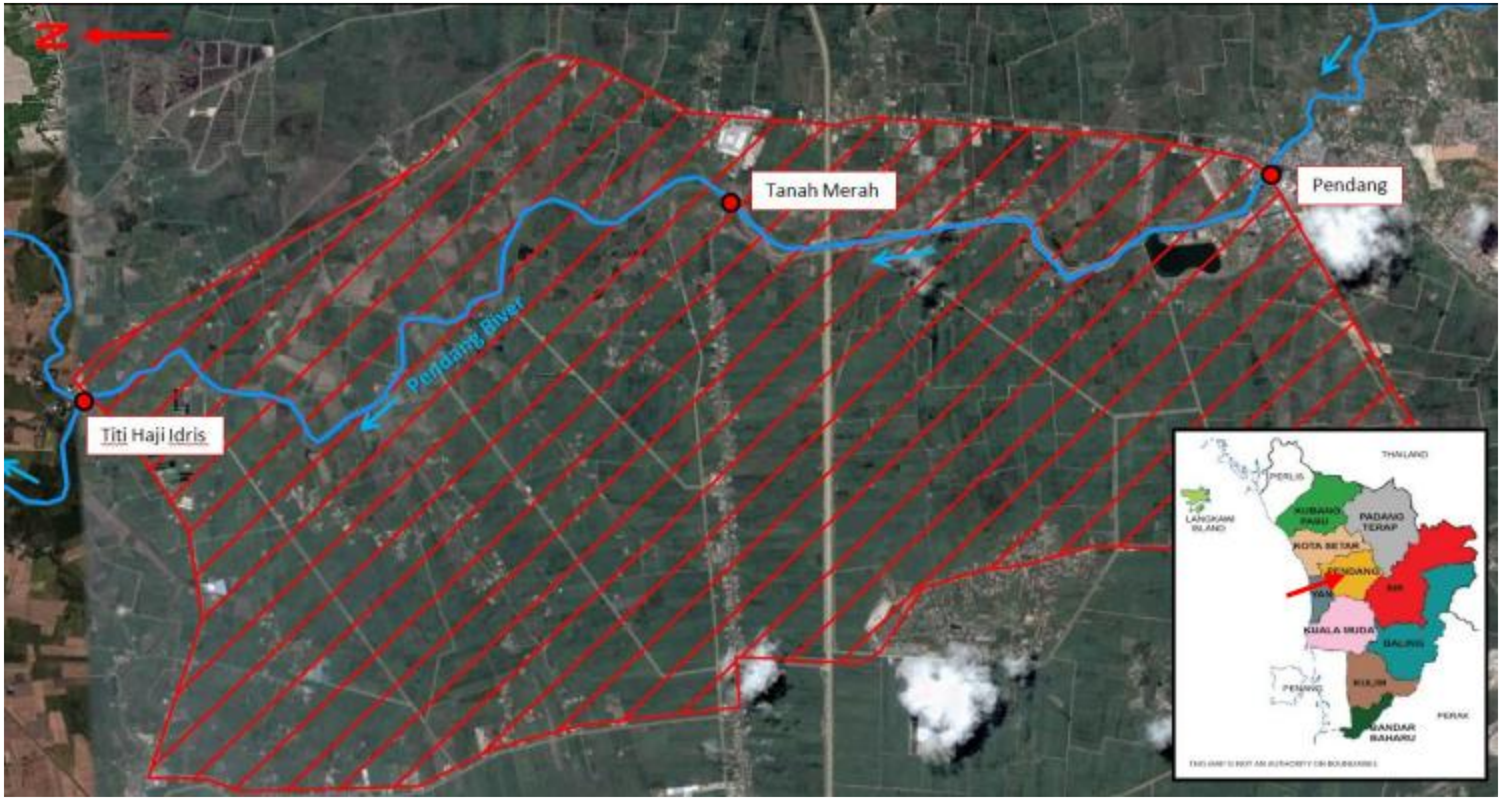
EVALUATION AND MONETARY ASSESSMENT OF MULTIFUNCTIONAL ROLES OF PADDY FIELDS

1. This study investigates the potentials of flood and sediment control in a specific study site in Malaysia.
2. The study was financed by MOA, Malaysia as an effort to address flood and sediment deposition problem in a major irrigation scheme, MUDA.
3. Through computer modeling, the behavior and response of flood water within paddy fiels located in floodplains were captured.

STUDY AREA

Wilayah III Pendang, Kedah

2.0 Introduction to case study



STUDY AREA

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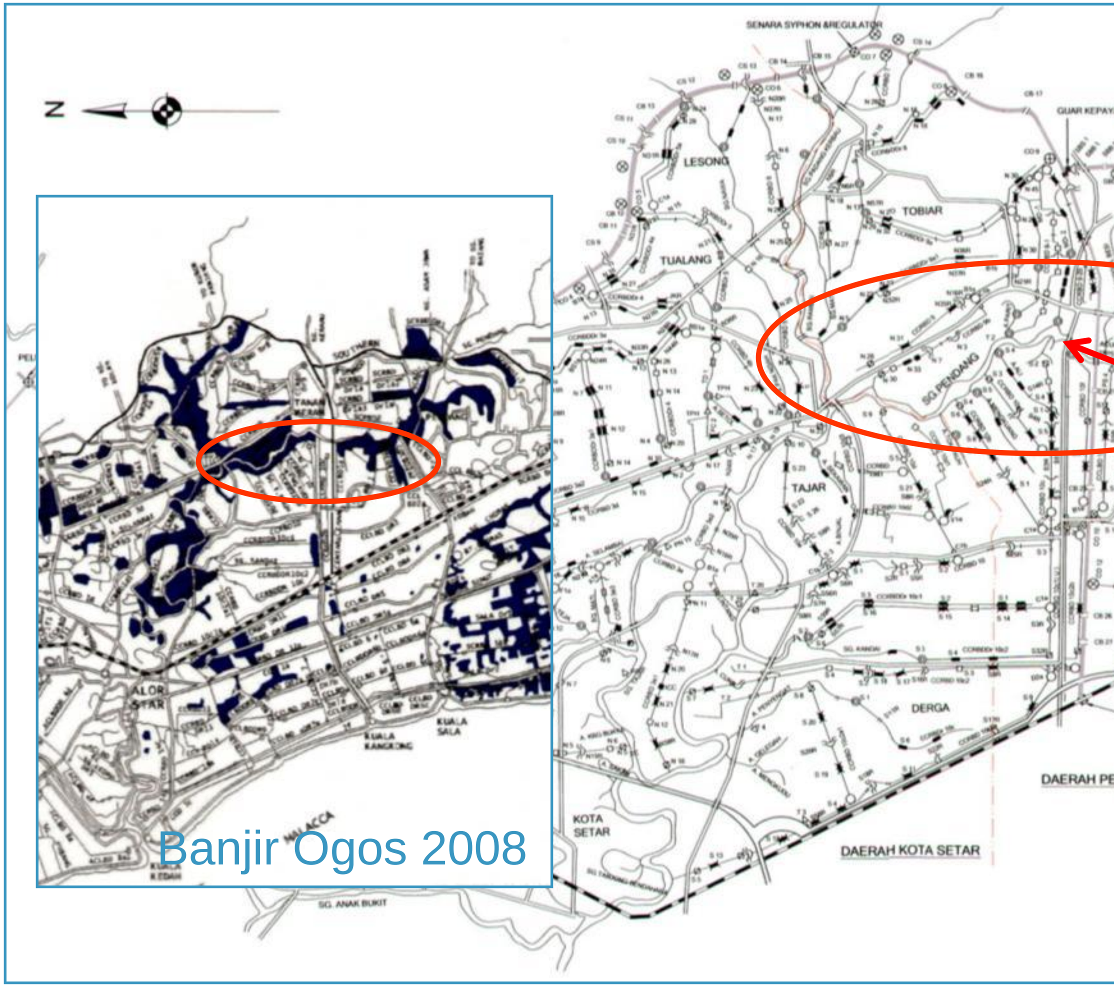
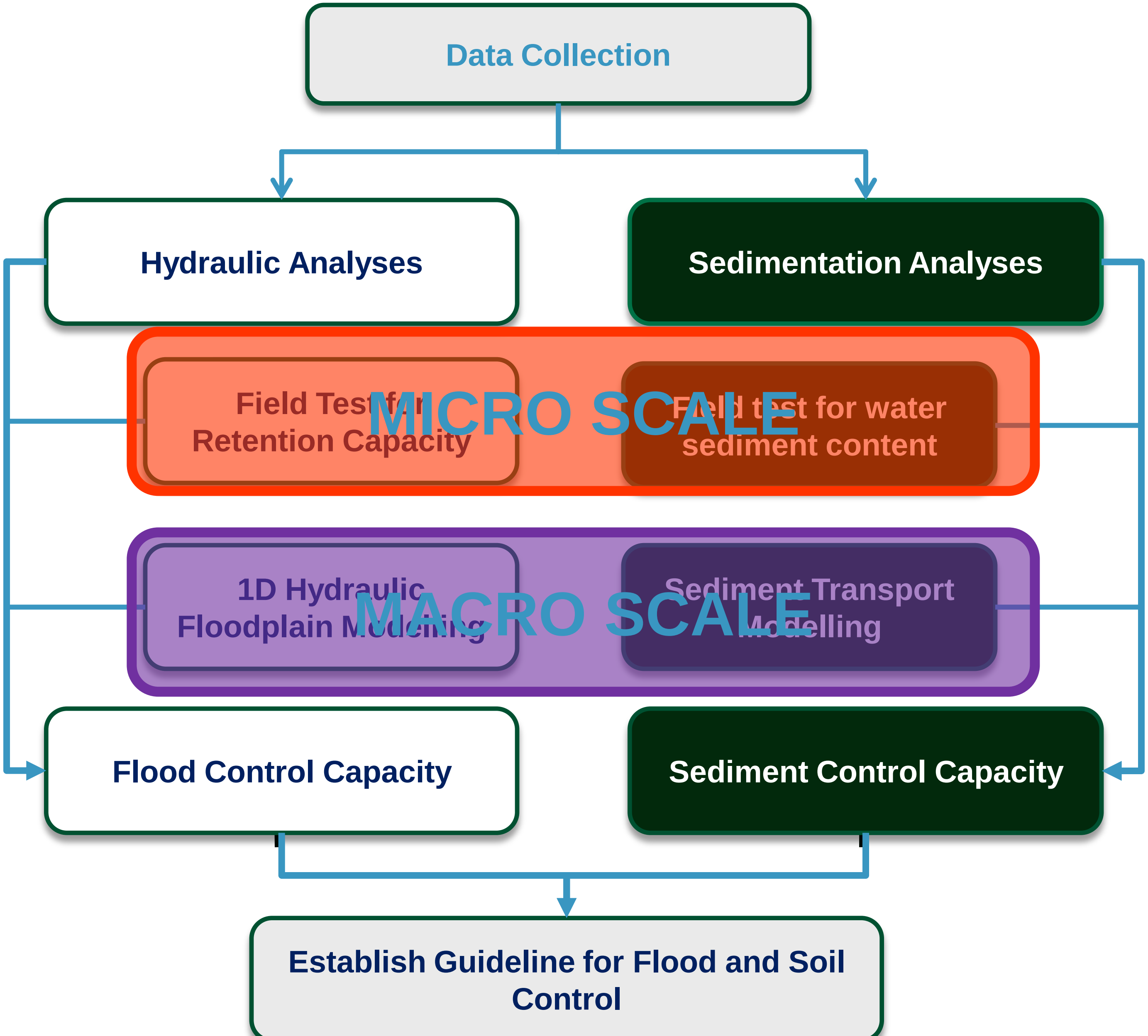


Methodology & Sequence of Work



Monetary Assessment

- The Cost Replacement Method (CRM) was applied to provide value estimation for both services, by equating the services to a manmade services/ products which serves similar function at the same magnitude.
- It can be more clearly expressed in mathematical terms, as given in this equation :

$$MV_{MF} = FV_{MF} \times UC_{CR}$$

- Where,

MVMF is the monetary value of an environmental service provided by paddy field,

FVMF is the quantity or magnitude of the function, and

UCCR is the unit cost of the replacement service chosen to represent the environmental service provided by paddy field.

- The replacement cost for flood control is the cost of a flood prevention dam while the replacement cost for sediment control is the cost for river excavation or desilting service.

4.0 METHODOLOGY

The eventual computations for flood control and sediment control functions are represented by Equations below:.

$$MV_{FC} = [(A_{EFF} \times D_F) + (A_{EF} \times H_L)] \times \left(\frac{\frac{C_C}{D_D} + \frac{C_{OM}}{D_S}}{V_F} \right)$$

Where,

MV FC is the monetary value:; *AEFF* i s the effective area of flooded paddy fields upstream of development,

DF is the average flood depth in paddy field,: *AEF* is the area of paddy field upstream of developments: *HL* is the average height of paddy plot levee; *CC* is the total construction cost: *DD* is the design life span of the dam; *COM* is the operation and maintenance costs, *DS* is the time span covered by the O&M schedule, and *VF* is the flood control capacity which the dam is designed to provide

Monetary Assessment

For flood volume contributed by individual plots retention capacity, the volume is computed by multiplying area which is upstream of development and the average height of levee.

Sediment volume was also converted into sediment trapping area (with an average depth determined through the sediment transport model).

A ratio of effective sediment trapping area (areas with sediment depositions and upstream of development) to total paddy planting area of a site was factored in to rationalize a more practical estimation of sediment trapping paddy fields area in the country

$$MV_{SC} = (A_{ES} \times D_s) \times \left(\frac{C_{RD}}{n \times V_S}\right)$$

4.0 METHODOLOGY

Paddy Field for Flood Control

Flat Levees of paddy plots serve as earth embankments to hold water for culturing rice crops, to provide access routes, and to divide crops for management purpose, and indirectly provide a storage basin to capture rainwater.

The large amount of water stored in the paddy fields might functions as many small reservoirs or dam. They hold rainfall in the fields, thus reducing peak flow and preventing flood. This rainwater capturing mechanism can be observed using water balance model.

The retention capacity of the paddy plot structure, coupled with evapotranspiration could significantly reduce runoff generation, preventing runoff built up at downstream areas.

On top of that, many lowland paddy fields are located within the floodplain of river systems. These paddy fields help preserve the natural terrain and vegetation of floodplains.

4.0 METHODOLOGY

Paddy Field for Sediment Control

- Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) is the most common soil erosion estimation method being used. However, the equation is less effective in lowland paddy area, as the dominant mechanism of sediment control is not erosion, but sedimentation.
- Lowland paddy fields, typically very flat, yield negligible erosion rate, but are very effective in providing space for sedimentation.
- Therefore, the conventional approach proposed by many researchers (USLE model) is not suitable to describe the sediment control function study area.

4.0 METHODOLOGY

Determination of flood control volume in Paddy Field

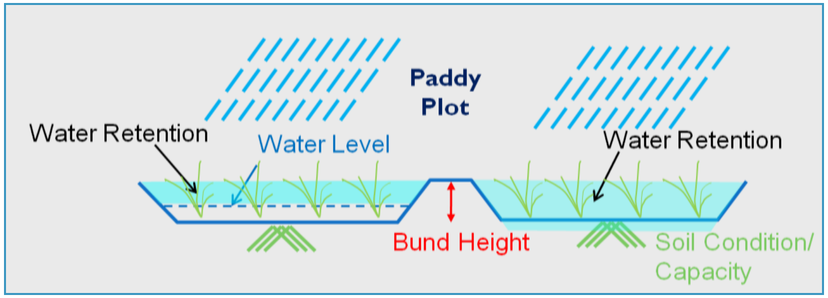
i. On top of reducing rainfall runoff, lowland paddy fields would also be able to attenuate flood as part of the floodplain system. To assess this flood control mechanism, a one dimensional hydraulic model, namely HEC-RAS (USACE, 2006) was used.
ii. Geographic Information System (GIS) based HEC-geo-RAS was used to prepare model setup by identifying river alignment, generating Digital Elevation Model (DEM) and manning's roughness of flood plain.
iii. Hydraulic boundary conditions (water level) at upstream and downstream were provided by irrigation water management authority
iv. The flood level generated by the HEC-RAS model would be imported into GIS software to generate the flood volume.

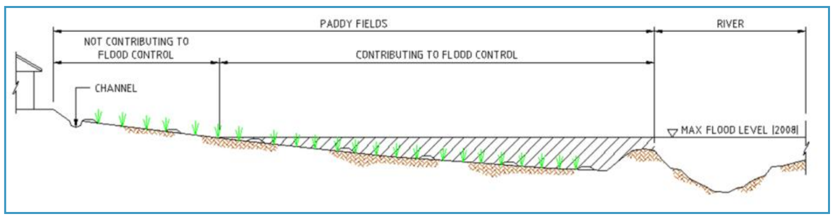
4.0 METHODOLOGY

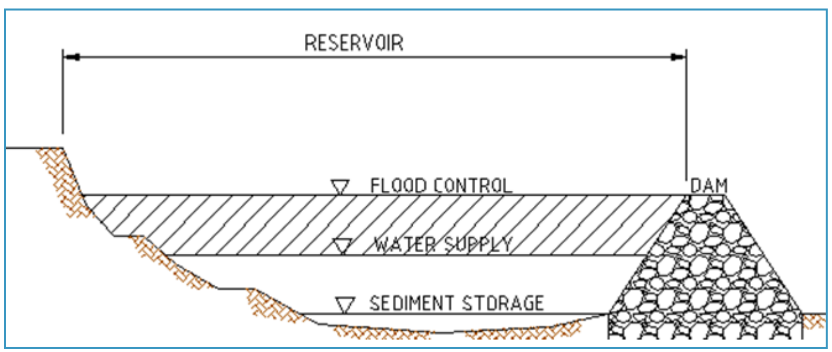
Paddy Field for Sediment Control

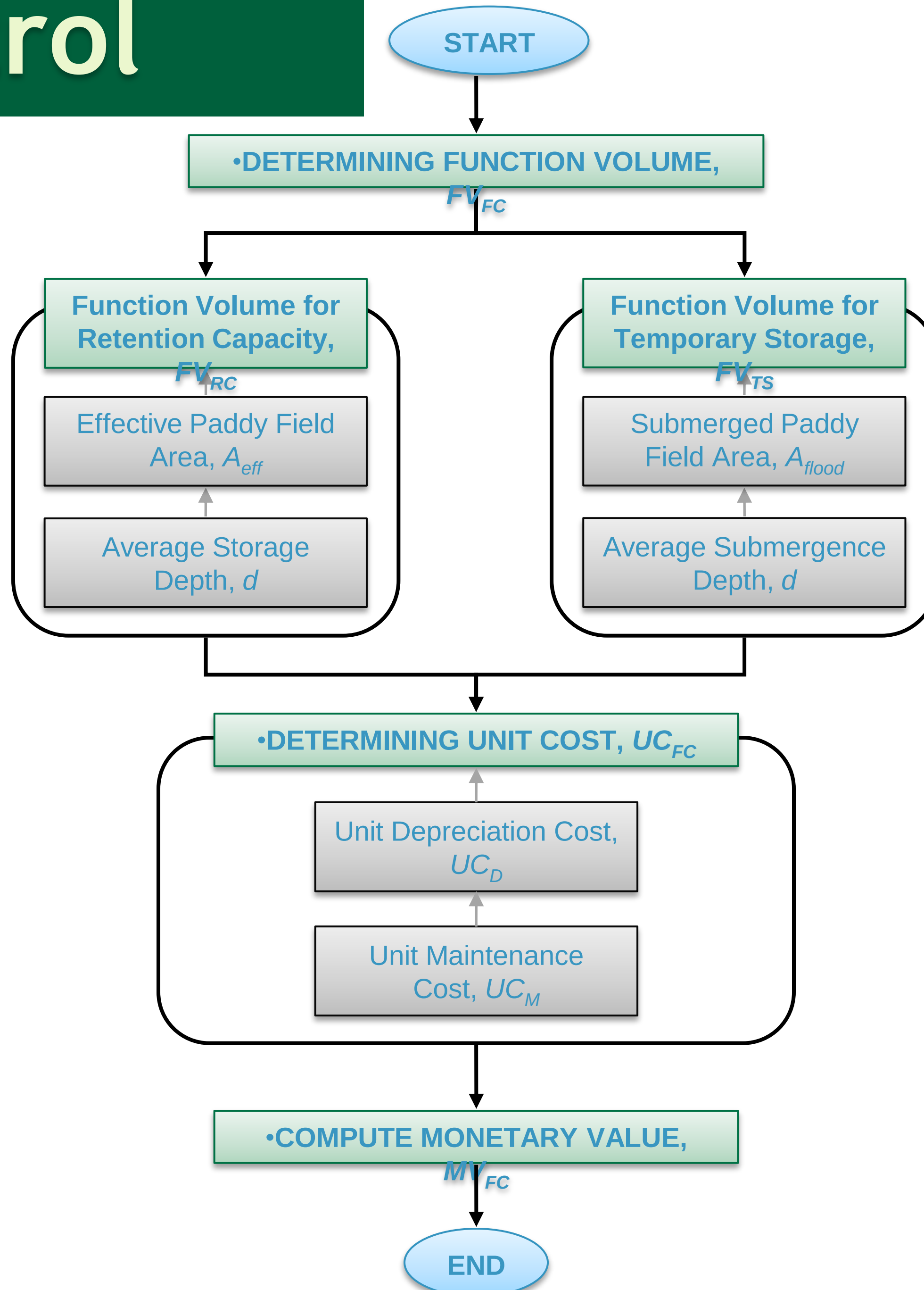
- To tackle this issue, the sediment transport model was introduced to assess the actual magnitude of sediment control function in a lowland paddy field.
- In this study, the sediment transport model was actually an extension from the existing HEC-RAS model used for flood control assessment. Sediment parameters such as suspended sediment and bed loads were inserted based on site sampling during a flood recession.
- The sediment transport model, utilising hydraulics and flow condition generated by HEC- RAS hydraulic engine, could predict the transport, settlement, re-suspension of sediments in the river (and floodplains).

Flood Control

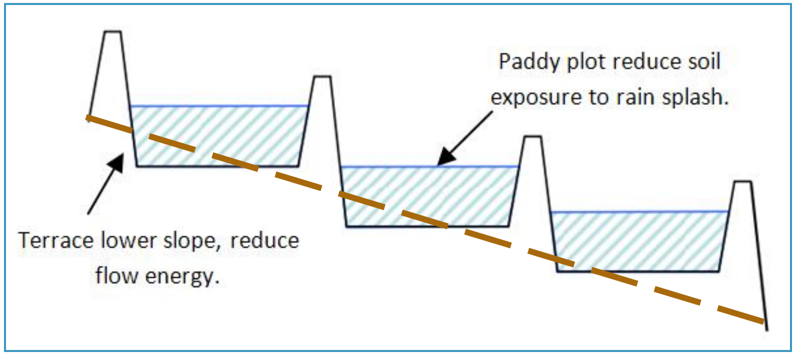


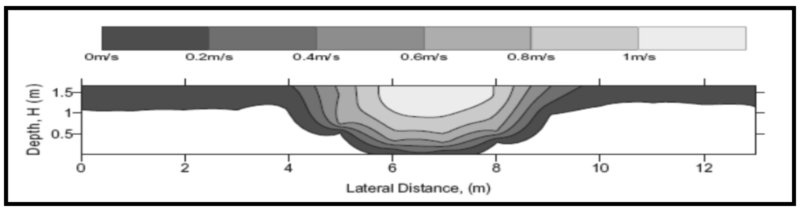






Sediment Control





START

LOWLAND PADDY: SEDIMENTATION APPROACH

- **DETERMINING FUNCTION VOLUME, FV_{SC}**
  - Sedimentation Rate during Annual Flood, A_{eff}
  - Average Sedimentation Depth, d
- **DETERMINING UNIT COST, UC_{SC}**
  - Unit Cost of Removing Sediment from River, UC_{RS}
- **COMPUTE MONETARY VALUE, MV_{SC}**

END

HIGHLAND PADDY: EROSION CONTROL APPROACH

- **DETERMINING FUNCTION VOLUME, FV_{SC}**
  - Erosion Rate per area for Paddy Fields (assumed abandoned) using Universal Soil Loss Equation, A
- **DETERMINING UNIT COST, UC_{SC}**
  - Unit Cost of Removing Eroded Soil from Land, UC_{RS}
- **COMPUTE MONETARY VALUE, MV_{SC}**

END

4.0 Result and discussion

Flood Control

Using HEC-RAS hydraulic model, the flood propagation in the river and its floodplains (paddy fields) can be sufficiently captured.

Figure 2a shows the river in HEC-RAS in November 2009 flood was „reproduced‟ (Figure 2b) and the effect of paddy fields as floodplain was studied.

Next, the study area was divided into northern (from Tanah Merah to Titi Haji Idris) and southern region (from Pendang to Tanah Merah), where paddy field floodplain was replaced with full development (raised ground level and urbanized) alternately.

It was found that without paddy fields, water level and flow rate rose significantly in both scenarios, posing serious flood hazard to downstream city (Alor Setar) (Figure 3).

The results confirmed the importance of paddy fields in preserving natural floodplain and providing flood attenuation.

Finally, the results of the model were summarized to provide basic information for monetary assessment as presented in Table 1.

4.0 Result and discussion

Figure 2.

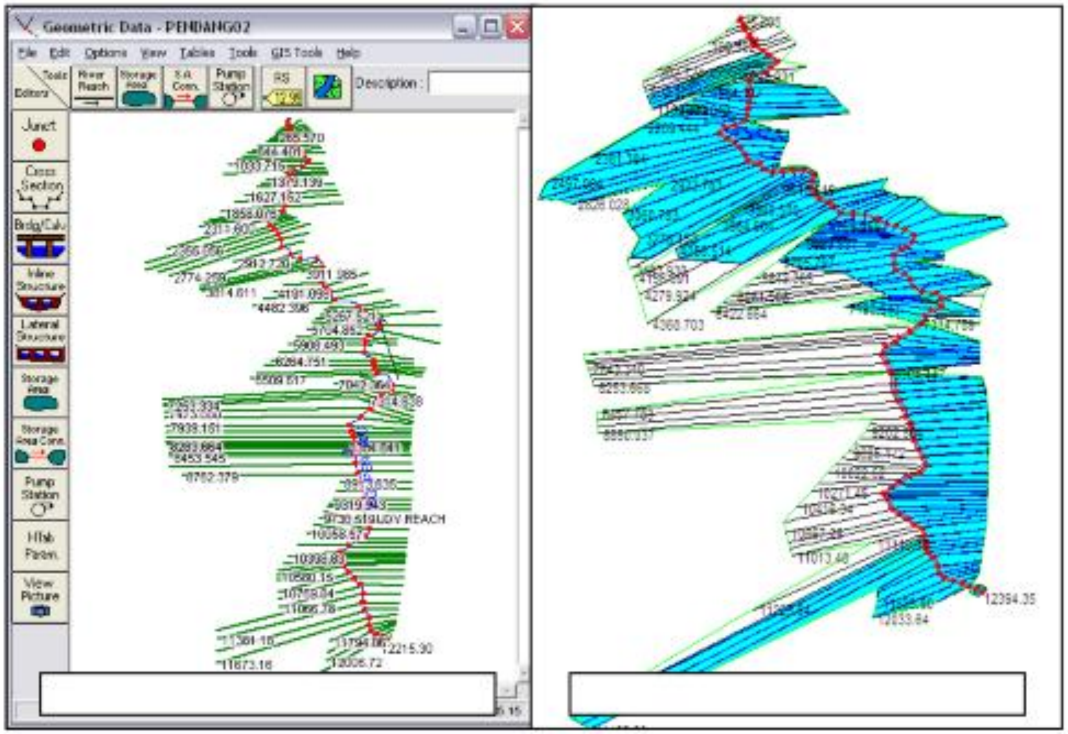


Figure 2: HEC-RAS Model of Pendang River in Study Area.

4.0 Result and discussion

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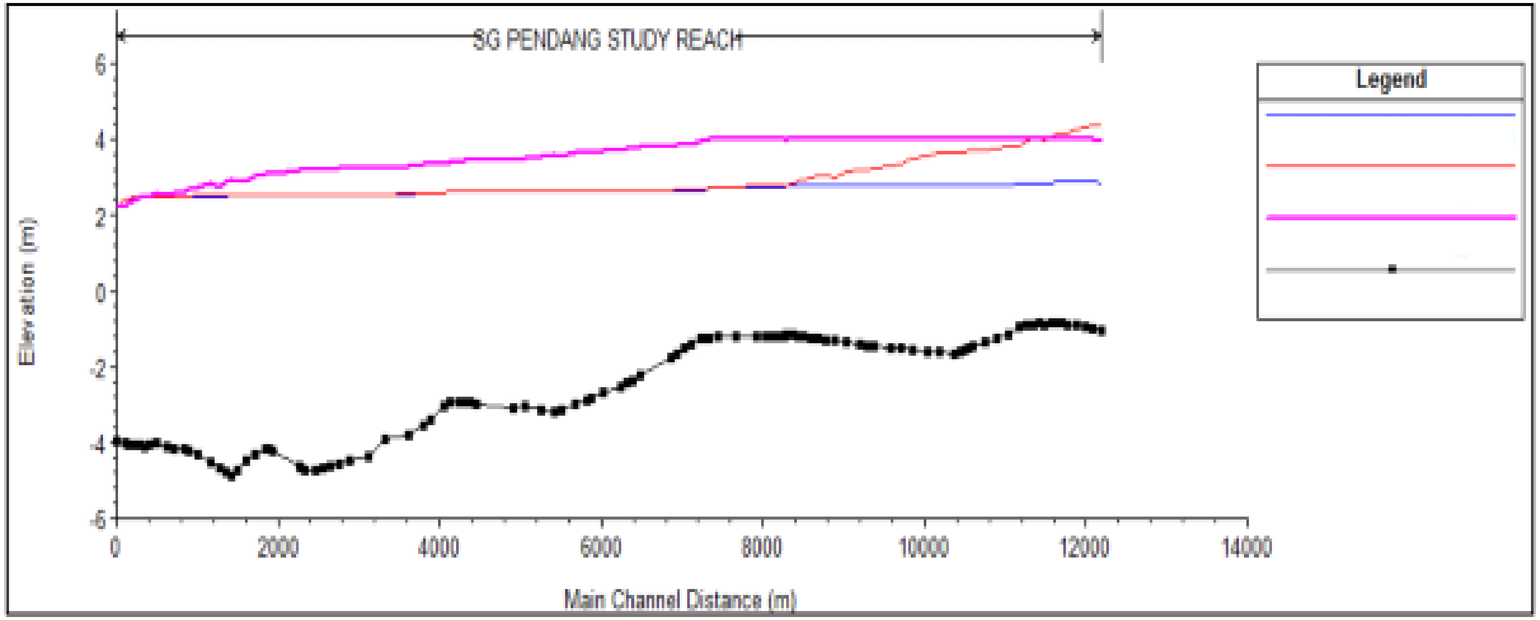

Figure 3: HEC-RAS Model of Pendang River in Study Area.

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4.0 Result and discussion

Table 1: Information of Flooding Extracted from the HEC-RAS Hydraulic Model

Results	Quantity
Total Flood Volume, m^3	3,688,934.9
Total Flooded Area, m^2	5,087,868.4
Average Flood Depth, m	0.73
Total Paddy Fields Area, m^2	24,901,999.0

Table 2: Properties of Lebir Dam Used to Derive the Unit Cost for Flood Control

Dam Properties	Values
Flood Control Capacity, V_F	25.6 million m^3
Total Dam Construction Cost, C_C	381.67mil USD
Dam Design Life Span, D_D	100 years
Total O&M Cost, C_{OM}	18.33 mil USD
O&M Schedule, D_S	10 years

4.0 Result and discussion

Sediment Control

- Sediment transport model built on the HEC-RAS hydraulic model was used to study the mechanism of sediment settlement in paddy fields during a flood. Figure 4 shows the mapped result based on the November 2009 flood.

- The result was verified by 6 core samples (inset Figure 4) collected from site after flood. A deposition of 2 to 5mm of sediment was found to be common in most areas.

- The model computed that the total sediment deposited in the study area was 9,356.473m3 on 2.71km2 of paddy fields.

- This yielded an average sediment deposition of 3.45mm, which fell within the range of the site samples.

4.0 Result and discussion

Sediment Control

Figure 4: Sediment Transport Modelling Result.

4.O Result and discussion

Monetary Assessment for Study Area

i. Monetary values of flood control and sediment control provided by study area was computed using the information obtained from the modeling exercises.
ii. For flood control, the function volume was derived from the flood model (determined as 3,688,934.9m3) and runoff detention approach (determined as 7,470,599.7m3) and since the site was located upstream of the Alor Setar City, the entire volume was considered.
iii. The unit cost for flood control function was derived from the cost of construction and operation of a dam. In this case study, the cost for proposed Lebir Dam in Malaysia was used.
iv. The final unit cost was found to be 0.22 USD per volume of water.
v. The computed monetary value for the study area was 2.45mil USD annually.

4.O Result and discussion

Monetary Assessment for Study Area

i. The function volume for sediment control was determined as 9,356.473m3, as given by the sediment transport model.

ii. The cost for a river dredging service was used to compute the sediment control unit cost, which was finalized at 6.67 USD.

iii. This yielded the monetary value of sediment control in the study area as 62,372 USD annually

4.0 Result and discussion

Table 3: Comparison of Monetary Value estimated for Multifunctionality of Paddy Fields in Malaysia

Monetary Value	Current Study	Yamaoko, 2009
Flood Control	440 mil USD	328 mil USD
Sediment Control	12 mil USD	33 mil USD

4.O Result and discussion

Yamaoko (2006) provided estimations on monetary values of multi-functionality for several environmental services provided by paddy fields in several paddy planting countries, including Malaysia.

Table 3 shows the comparison of monetary value estimation made. The value of flood control function of this study is higher than that suggested by Yamaoko (2006) because the additional value contributed by considering paddy fields as floodplain.

The use of different approach was also the cause of discrepancy for monetary value estimations for sediment control.

The application of USLE (as used by Yamaoko, 2006) was impractical for extreme flat lowland paddy planting in Malaysia.

4.O Result and discussion

Limitation of Monetary Assessment

Economics benefits of natural ecosystems, paddy fields are difficult to be accurately assessed.

i. Difficulty in quantifying the magnitude or extent of such services.
ii. Uncertainties in determining unit monetary cost to the services.

4.O Result and discussion

Guidelines for Monetary evaluation for various function of paddy fields

1. INWEPF is in the process of compiling the findings from case studies such as above from member countries into Guidelines for monetary evaluation for various function of paddy fields
2. After a series of technical discussions and review, a unified standard protocol for monetary assessment will be produced.
3. Guidelines the flood and sediment control functions had been finalized while others are in progress.
4. Contents of the proposed monetary assessment guidelines for each function

- Concept of Function
- Valuation Procedure and Flow Chart
- Monetary Assessment
- Case Study

GUIDELINES FOR MONETARY ASSESSMENT OF FLOOD AND SEDIMENT CONTROL IN PADDY FIELDS

5.0 Conclusion

1. There is a need to balance in increase of agricultural productivity with the environmental protection as the increase in productivity most of the time give effects to environment, water demand and poor farmers.
2. Paddy field and irrigation system provide various benefit, socially, economically, environmentally and culturally through its multifunctional roles and uses.
3. Evaluation and conducting monetary assessment is required to quantify the value of the functions to consider during overall project evaluation.
4. INWEPF has taken the task to promote efforts for sustainability and multi-functionality of paddy system. Providing guidelines for monetary assessment for flood control and sediment in paddy fields is one of such efforts.

Thank you

For your attention