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CASE STUDY FOR MONETARY ASSESSMENT OF FLOOD CONTROL AND SEDIMENT CONTROL FUNCTION OF PADDY FIELDS IN MUDA IRRIGATION SCHEME, MALAYSIA.

ÉTUDE DE CAS SUR LA COMPENSATIONMONÉTAIRE DE LA REGULARISATION DES CRUES ET LA COMMANDE DE FONCTION DE SÉDIMENTS DES RIZIÈRES POUR LE SYSTÈME D'IRRIGATION DE MUDA EN MALAISIE.

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ABSTRACT

It has been widely perceived that large scale paddy planting in Asian countries are contributing to degradation of the environment mainly through destruction of ecosystem and methane gas emission. Paddy fields serve as artificial wetland which has multi-functionality such as flood control, sediment control, and ground water recharge and ecosystem preservation and provides a broad range of benefits in the social, cultural and environmental aspects to the region. This study investigates the potentials of flood and sediment control in a specific study site in Malaysia. The case study was conducted in the Muda Irrigation Scheme in Malaysia. Study area covers approximately 25km2, located in floodplain areas are intelligently used for flood control and sediment control. Through computer modelling, the behaviour and response of flood water within paddy fields located in floodplains were captured. Physical structures of paddy fields greatly increase the capacity for flow retention and sediment deposition. Subsequently, these important findings were translated into monetary value for appreciation of wider audience. Cost replacement method was used to equate the flood control and sediment control value of paddy field to equivalent flood prevention dam and river de-silting projects. It was found that the values of flood and sediment control were conservatively estimated to be 440mil USD and 12mil USD respectively.

RÉSUMÉ

Il a été largement perçu que les plantations de rizières à grande échelle dans les pays asiatiques contribuent à la dégradation de l'environnement, principalement par la destruction de l'écosystème et l'émission de méthane. Les rizières servent aussi comme des marécages artificiels qui sont multifonctionnelles telles que pour le contrôle des inondations, le contrôle des sédiments, recharge de la nappe phréatique et la préservation de l'écosystème. Elles fournissent également une large gamme de prestations en matière sociale, culturelle et environnementale à la région. Cette étude examine le potentiel de contrôle des inondations et des sédiments sur un site d'étude spécifique en Malaisie. L'étude de cas a été menée au système d'irrigation de Muda en Malaisie. La zone d'étude couvre environ 25km^2, située dans des zones inondables sont intelligemment utilisés pour la régularisation des crues et le contrôle des sédiments. Grâce à la modélisation informatique, le comportement et la réaction des eaux de crue dans les rizières situées dans des zones inondables ont été capturés. Les structures physiques de rizières augmentent considérablement la capacité de rétention de l'écoulement et le dépôt de sédiments. Par la suite, ces résultats importants ont été traduits en valeur monétaire pour l'appréciation du public plus large. La méthode du coût de remplacement a été utilisée pour assimiler la valeur de régularisation des crues et des sédiments de la rizière en barrage de la prévention des inondations équivalent et des projets de-envasement rivière. Selon une estimation prudente, il a été constaté que les valeurs de régularisation des crues et de sédiments ont été respectivement estimées à 440 millions de Dollar et 12 millions de Dollar.

Keywords: multi-functional; paddy fields; Muda Irrigation Scheme; flood control function; sediment control function; monetaryassessment of the function; Cost replacement method.

INTRODUCTION

1.1 Background

Theterm ‘multi-functionality’refers to an agriculturalactivity thatcouldhavemultiple outputsbesidesprovidingfoodand fibresand,therefore, may contributetoseveral objectives at once.The multiple roles of agriculture includefood security, maintaining andensuringviabilityofruralcommunitiesandenvironmentalprotection,suchas landconservation, sustainable managementofrenewablenatural resources, preservationofbiodiversity,landscape,etc.Matsunoet al.(2006)summarized brilliantly fromrichset ofliteratures,comprising ofover 200documents on major externalfunctionsofpaddy fields.Thestudysummarisedtheenvironmentalservices providedbypaddy fields,namely, floodcontrol,groundwaterrecharge,erosion control,water purification,climate mitigation,andbiodiversity conservation.Yoon (2009)hascomparedtheenvironmentalservicesprovidedbypaddy fieldstonatural wetland,whichintheauthor’sstudy,wasfoundtopartially compensatethelossof natural wetland. Yamaoka(2009)provides amoreholistic evaluation byestimatingmonetaryvaluesofseveralenvironmental functions providedby paddy fieldsinseveralrice-producingcountries. Ithas beenacommon agreementthatthevalueofthe multi-functionality ofpaddy fieldssignificantly out- weightthevalue oftradablecommodityproduced(rice).

Uponreview ofthemethodology usedinestimating floodandsedimentcontrols,it was foundthatcertainimprovementcouldbemadetomoreaccurately capturethe valueofthesefunctionsinpaddy fields.Itis onthebasisofsuchdifferent approach thatthecurrentstudy wasconducted,whichistofirstprovethevalidity oftwo hypothesis(floodcontrolthroughpaddy fieldsin floodplain, and sedimentcontrol throughsedimentation),andsubsequently quantify thecontributionsofsuch mechanismtothemonetaryvalueof multi-functionalityofpaddyfields inMalaysia.

1.2 StudyArea

Theselectedstudy siteisa12kmstretchof frequently floodedPendangRiverinthe stateofKedah,Malaysia. Thesitecoversthestretch fromPendangTowntoTitiHaji Idristogetherwith floodplainsmadeupofirrigatedpaddy fieldsonbothsidesofthe river. Totalareaof thestudy areaisalmost 25km^2. Thissiteisunderthe administrationofMudaAgriculturalDevelopmentAuthority(MADA).Figure1gives anoverviewofthestudyarea.ThePendangRiverisfrequentlyfloodedduringthemonsoonperiods,submerging paddy fields(floodplains)along the river. Thestudy siteisvery flat(anaveragelongitudinal slope offloodplainaround1:10,000). Further downstreamfromthe study area,theriverwouldeventually flow throughAlorSetar City, the state capital and central businessdistrict ofthe Kedah State

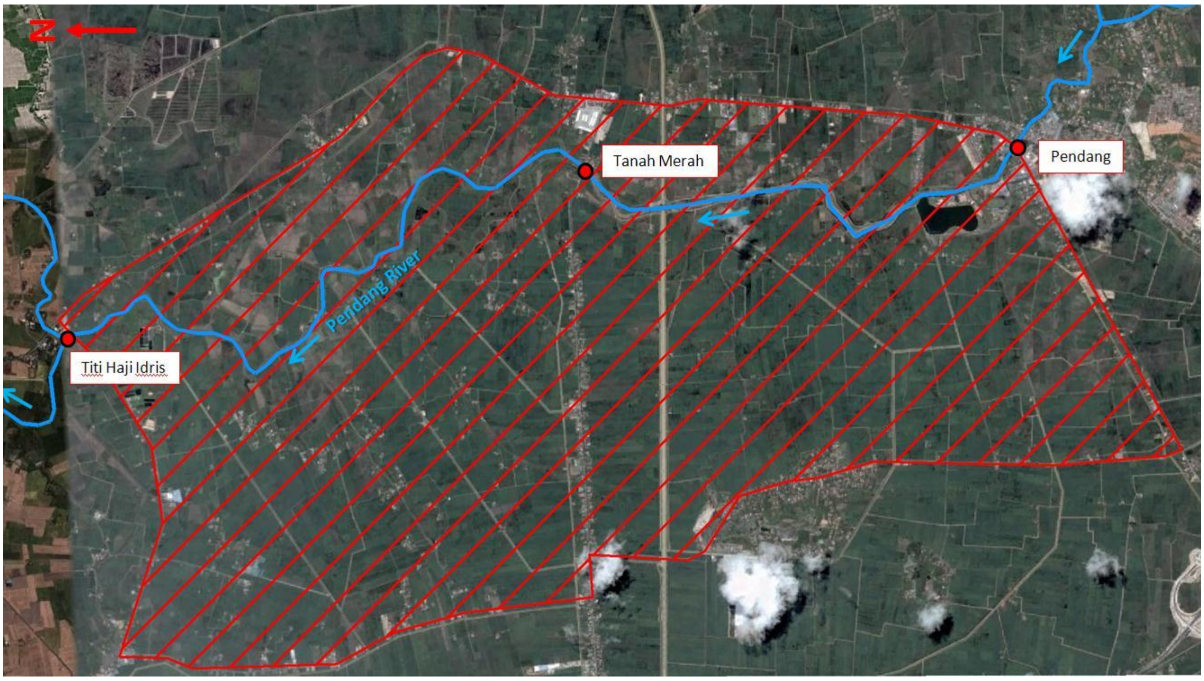

Figure 1: Study Area

2. METHODOLOGY

2.1 PaddyFieldfor FloodControl

Toassessthis floodcontrol mechanism,aone dimensionalhydraulicmodel, namely HEC-RAS(USACE,2006)wasused. GeographicInformationSystem(GIS) basedHEC-geoRASwas usedtoprepare modelsetup by identifyingriveralignment,generatingDigitalElevationModel(DEM) andmanning'sroughnessoffloodplain.Hydraulicboundaryconditions(waterlevel) at upstream (Tanah Merah) and downstream (TitiHaji Idris) were provided by MADA.ThefloodlevelgeneratedbytheHEC-RASmodelwouldbeimportedinto GISsoftware togeneratethefloodvolume.

2.2 PaddyFieldfor SedimentControl

Sedimentcontrolfunctionofpaddy fieldcanbelookedintofromerosionand sedimentation perspectives.UniversalSoilLossEquation(USLE)(WischmeierandSmith,1978)isthemostcommonsoil erosionestimation methodbeing used.However,the equationisless effectiveinlowlandpaddy area, asthedominantmechanismof sediment controlisnoterosion,butsedimentation. Lowlandpaddy fields, typically veryflat(gradientof 1:10,000is notuncommon), yield negligible erosionrate,but are veryeffectivein providingspacefor sedimentation. Therefore,theconventionalapproachproposedby many researchers(USLEmodel) isnot suitableto describethesediment controlfunctioninMalaysia.Totackle this issue,thesedimenttransportmodelwasintroducedtoassesstheactualmagnitude ofsedimentcontrol functioninalowlandpaddy field.Inthisstudy,thesediment transportmodelwasactuallyanextensionfromtheexistingHEC-RASmodelused forfloodcontrolassessment.Sedimentparameterssuchassuspendedsediment andbedloadswereinsertedbasedonsitesampling during a flood recession. The sedimenttransportmodel,utilising hydraulicsandflow conditiongeneratedby HEC- RAShydraulic engine,could predictthetransport,settlement,re-suspension of sedimentsin theriver (andfloodplains).

2.3 Monetary Assessment

Monetary valueofenvironmental benefits providedbythepaddyfieldsforthestudy areawascomputed.TheCostReplacement Method(CRM)wasappliedto provide valueestimation for bothservices,by equatingtheservicestoamanmadeservices/ productswhichservessimilarfunction atthe same magnitude. Thereplacementcost for flood control was to be the cost of a flood prevention dam while thereplacementcost forsedimentcontrol waschosentoberiverdesilting/excavation service.
By relatingthecapacity providedby paddy fieldsisequaltothecapacity ofa flood prevention dam, itcan be then assumedthatthecosttoconstruct andoperate the damfor floodcontrolcansufficiently representthecostof floodcontrolprovidedby paddy fields.Thevolumeof floodwaterwasderivedfromtwosourceduetothe differentmechanismof paddyfieldsinprovidingfloodcontrol,i.e.asfloodplain (volumederived fromtheHEC-RAS modelsimulation)and asrunoffdetention units (volumederivedby multiplyingpaddy fieldsareatoaverageheightoflevee,as describedbyYamaoko,2009).Theunitcostforfloodcontrolfunctionofpaddyfield is represented by the sum of dam construction and operation costs per water volume.

CRMwasalsousedforsedimentcontrolfunctionmonetary assessment.The replacementcost usedwasthecost ofriver dredging maintenanceworktoremove thesameamountofsedimentsastrappedbypaddy fields.Intheabsenceofthe paddy fields assedimenttraps,sedimentswouldbetransportedfurtherdownstream, settle out somewhere near to river mouth, and eventually require dredging to maintainrivermouthcapacity.Thevolumeofsedimenttrappingcapacity ofpaddy fieldswas determined usingthesediment transportmodel(thevolume ofsediment depositedwithinthepaddyfieldsafteraflood).Unitcostreferstothecostper volumeofsedimentbeingdredged,transportedandproperlycuredanddisposedin ariver dredgingwork.

Finallya preliminarynational projectionwas carried outtoestimatemonetaryvalues ofpaddyfieldsflood andsedimentcontrolfunctionsusingthenewassessment approaches.Inorder tosimplifythecomputationoffunctionvolumes,several modifications were introduced;

- Floodvolumewasconverted intoflood inundation area (with anaverage depth determined through the HEC-RAS model). A ratio ofeffective flood inundation area(areas whicharesubmerged and upstreamofdevelopment) to totalpaddyplantingarea ofa site wasfactored in to rationalize a more practical estimation offloodcontrollingpaddyfields areainthecountry.
- Forfloodvolumecontributedbyindividualplotsretentioncapacity,thevolume iscomputedbymultiplyingareawhichisupstreamofdevelopmentandthe average heightoflevee.
- Sedimentvolumewasalsoconvertedintosedimenttrappingarea(withan averagedepthdeterminedthroughthesedimenttransport model). Aratioof effectivesedimenttrappingarea(areas withsedimentdepositionsand upstreamofdevelopment)tototalpaddyplantingareaofasitewasfactored intorationalizeamorepracticalestimationofsedimenttrappingpaddy fields areainthecountry.

3. RESULT& DISCUSSION

3.1 Flood Control

Using HEC-RAS hydraulic model, the flood propagation in the river and its floodplains(paddy fields)canbesufficientlycaptured.Inthisstudy,theNovember 2009 flood was„reproduced" andtheeffectofpaddy fieldsas floodplainwasstudied.Next,thestudy areawas dividedintonorthern(from Tanah MerahtoTitiHajiIdris) andsouthern region(fromPendangtoTanahMerah),wherepaddy fieldfloodplainwasreplaced withfulldevelopment (raisedgroundlevelandurbanized)alternately.Itwasfound that without paddy fields, water level and flow rate rose significantly in both scenarios,posingseriousfloodhazardtodownstreamcity(AlorSetar). Theresultsconfirmedtheimportanceofpaddyfieldsinpreservingnaturalfloodplain

3.2 SedimentControl

Sedimenttransport model builtontheHEC-RAS hydraulic model was usedtostudy themechanismofsedimentsettlementinpaddy fields duringaflood.Figure4shows themappedresultbasedontheNovember2009flood.Theresult wasverifiedby6 coresamplescollectedfromsiteafterflood.Adepositionof2to 5mmofsedimentwasfoundto becommoninmostareas. The modelcomputedthat thetotal sedimentdepositedinthestudyareawas 9,356.473m^{3}on2.71km^{2}ofpaddy fields. Thisyielded an averagesedimentdepositionof3.45mm,which fellwithinthe rangeofthesitesamples.

3.3 MonetaryAssessmentfor StudyArea

Monetary valuesoffloodcontrol andsedimentcontrol providedbystudy areawas computedusingtheinformationobtained fromthemodelling exercises.
Forflood control, the function volume was derived from the flood model (determined as 3,688,934.9m^3) andrunoffdetention approach(determined as 7,470,599.7m^3) and sincethesitewaslocated upstreamofthe AlorSetarCity,the entirevolumewas consideredwithoutanysubtractionofineffectivearea. Theunitcostfor floodcontrol functionwasderivedfromthecostofconstructionandoperation ofadam. Inthis casestudy,theproposedLebirDaminMalaysia.Thefinalunitcostwasfoundto be0.22USDpermeter cube volumeof water. As aresult,thecomputedmonetaryvaluewas 2.45milUSD.

Thefunctionvolume forsedimentcontrolwasdeterminedas9,356.473m^3,asgiven by thesedimenttransportmodel. Thecostforariverdredgingservicewasusedto computethesedimentcontrolunitcost,whichwasfinalizedat6.67USD.This yieldedthemonetary valueofsedimentcontrolinthestudy areaas 62,372USD annually.

3.4 NationalProjectionofFloodandSedimentControl MonetaryValues inMalaysia

Themonetaryvalueofthepaddyfieldonfloodcontrolatnationallevelcanbe roughlyestimatedbasedonfindingsofcurrentstudy.Alinearextrapolationwas usedtopredictthemonetary valueof floodcontrol function forpaddy fieldatnational level. Thisisdoneby equatingthemonetary valueofthefloodcontrolandsediment controlfunctionsfoundfor thesite to thenational total paddyplantingarea.

Asof2009,thetotalpaddyplantingareainthecountrycoversabout6,723 km^2 ofland(IRRI,2011).Considering only theeffectiveflooded paddy fields,i.e.only paddy fieldsthat are flooded and arelocatedupstreamofdevelopment,thetotal effective areawasdeterminedas1,352.4km^2. Thevolumeofthe floodcontrolcapacity by floodplain approach (987,252,000m^3) was determined by multiplying effective floodedareawiththeaveragefloodddepthfrompreviousmodelling exercise(0.73m), whereas the volume provided byrainfallrunoff reduction approach (1,014,300,000m^3)wasdeterminedbymultiplyingeffectivearea(assumedtobe 50%ofthetotalpaddy areaofMalaysia)withthe averagelevee heightofpaddy plot (0.3m).Finally,themonetary valueof floodcontrolfunctionprovidedby paddy field was estimatedtobe440milUSD,usingtheunit costderived(0.22USD).
Theprojection ofsedimentcontrol function toa nationallevelrequiresaslightly differentapproach.Anaveragedepthmethodusedforfloodcontrolprojectionwas notsuitablein thiscase,wherethe depositionofsedimentwasnot inahomogenous oruniformmatter. Whileflooddeptharealmostthesame,sedimentdeposition dependsonmuchmorefactors such asflow velocity.Therefore,acorrelationwas be establishedbetween

sedimentdepositionandfloodextendbyusingtheinformationfromstudyareabyobtainingaratioofsedimentdepositedvolume(9,356.473m^3)overfloodextent(5,087,868.4m^2). Theratio(determinedas0.0018)wasusedto projectthenationalsedimentdepositionbasedontheknowledgeoftheeffective area of paddy fields (987,252,000m^3) involved in flood control function in this country, which was estimated at 1,777,053m^3. Subsequently, the estimation monetary valuefornationalpaddy fieldsedimentcontrolfunctionwasabout11.8mil USD.

The computedsedimentvolumefunctionwascomputedbasedonthe depositedsediments atthestudy siteduring anannual flood.Sediment transport isacomplex and dynamicprocess,whichdepends heavily onthe hydraulics oftheriver. Ontopofthatthesedimentcharacteristicsalsoplayapartindeterminingthe amountofsedimentdeposited.Hencesedimentdepositioncanvaryfromone site toanother, justasfloodpropertiesmentionedearlier.

The monetary assessmentcould beimproved by havingmorecasestudiessuchas thatconducted.Further studies aretobeconductedtoinvestigateandattemptto improvethelimitations ofcurrentwork.Mostimportantly,emphasizewillbegivento deriveanationwidestandardguidelinefor monetary assessmentfor multi-functionalityofpaddyfields

4. CONCLUSION

This paperoutlinedthelimitationstomonetary assessmentofnaturalecosystemin generalandofthisstudy inparticular.Theseuncertaintiesare universallimitations andcanvary significantly.The main objectiveofthis assessmentincurrentstudy is nottoprecisely quantifythemonetary valuesofpaddyfieldsuptoeverysinglecent, buttoprovidearelatively reasonablestaturetotheseservicesinterms ofmonetary value.Themainobjectiveofthisassessmentistoincreasetheawareness fornon-technicalpartiesoftheimportanceofsuchservices.Atthesametime,italsohelps toprovideaneasierconsiderationplatformfordecision makersduring policy making ordevelopment planningstageswherethey cannow weightthese benefits against thepotentialeconomic benefitsofotheroptions ataneven platform.

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