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IMPACTS OF CLIMATE CHANGE ON AQUACULTURE IN GIAO XUAN COMMUNE, GIAO THUY DISTRICT, NAM DINH PROVINCE, VIETNAM

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Abstract

The study estimates impact of climate changes in clam culture in Giao Xuan commune, Giao Thuy district, Nam Dinh province - one of five communes in the buffer zone of Xuan Thuy National Park. The study estimates the losses due to climatic changing using the hazard risk assessment methodology of International Center for Geo-hazards (ICG). The method uses the natural hazards-based approach based on the uncertainty of climate change scenarios and the climate-related sensitiveness of clams in particular and bivalves in general. The analysis finds that sea surface temperature is the biggest factor affecting clam culture beside storms. By 2030, the clam production of Giao Xuan commune could reduce by about 26% compared to the current production, reduce by 36.5% in 2050 and 57.5% in 2090. The study reaffirms the importance of solutions to minimize the impacts of climate change on aquaculture in the North of Vietnam.

Keywords: Climate change; Economic impact; Clam culture; Hazard damage estimation.

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1. Introduction

With a long coastline (more than 3,000 km), Vietnam is identified as one of the most vulnerable countries due to climate variables and climate change [19]. Vietnam also ranks the 6th in the world for Climate change Risk Index (CRI) in the period of 1991 - 2010 [7]. Aquaculture is the most vulnerable due to climate change. According to the most recent report 2nd Climate Vulnerability Monitor [3], Vietnam is estimated to suffer from the greatest losses with current impacts estimate to 1.5 billion dollars per year (2010) and could experience losses in excess of 20 billion dollars per year by 2030.

This paper will focus on Giao Thuy clam culture - a famous brand name in Red River Delta which contributes 44% to the total clam production of the North of Vietnam. Being relied on environmental conditions, clam culture is very vulnerable to climate change and is expected to be influenced strongly by climate change. There is a growing concern that climate change with the increase in temperature, and salinity has partly contributed to the sudden clam deaths widely in Vietnam [10]. Clam production, is affected and there has been a huge loss to aquaculture in general and also the livelihood of the coastal community. However, there has been little research on estimating the economic impact on aquaculture and calculating the potential losses.

The objectives of the analyses are twofold. The first is to determine the likely magnitude and rate of decline on production and economic return from clam production due to high temperatures. The second objective is to identify solutions to minimize losses in clam production due to temperature change. This research is very valuable to provide concrete evidence for policy-makers to decide the most appropriate plan and strategy for the local community in a changing climate.

2. Description of Study Area

The study focused on the commune of Giao Xuan, Giao Thuy district, Nam Dinh province, within a relatively plain flat- one of key economic zone of Red River Delta. Giao Thuy is one of three coastal districts in Nam Dinh province, about 45 km to the east - southeast from Nam Dinh city, and 150 km to the southeast of Hanoi. As a part of the buffer zone of Xuan Thuy National Park (approved as a Ramsar Demonstration Site in 1989), this area is characteristic of tropical monsoon with two distinct seasons: a hot season (from April to October) coinciding with a rainy season and a cold dry season (November to March). The average temperature is 24^{o}C, average humidity is 84% and the average rainfall is 1,700 - 1,800 mm. It is influenced by the Red river system through Ba Lat estuary. The offshore's salinity from Ba Lat river mouth is 33$^o/_{oo}$ and varies 5 - 20$^o/_{oo}$ of the river mouth. The tide in this area is Diurnal tidal regime, tidal amplitude is around 1.5 - 1.8 m, the highest is 3.3m and the lowest is 0.25 m [14].

Giao Xuan, one of five buffer zone communes of Xuan Thuy National Park, has 1,292 ha in area and a population density of 1,291 people/km^2 [2]. The key livelihood activities include agriculture, aquaculture (50% of total income), capture fisheries (36%), and services (14%) [2]. Among them, clam culture is a new key development orientation of the Giao Thuy district with huge growth and development in recent years creating a sustainable livelihood for the community.

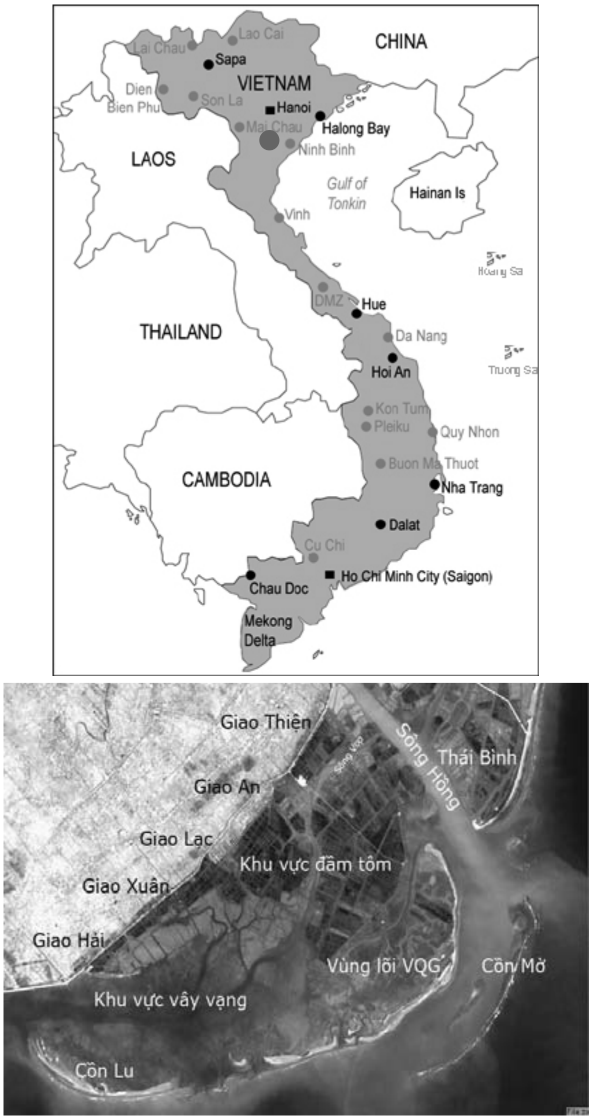

Figure 1: Study area map

The clam production areas of Giao Xuan commune are affected and exposed to the direct impacts of climate change as sea levels rise, and temperature and rainfall patterns change [1]. Clam culture operation depends heavily on climatic conditions, notably including extreme weather events and hazards, water salinity, and rising temperatures. With the dynamic interaction between two major rivers, the sea has created ecosystem of wetlands in the Giao Thuy district, typical to Xuan Thuy National Park. In addition, with the distribution of silt every year, two important effects of this process are affecting the process of salinity. This is reflected by changes in salt concentration in each period. In the winter, the salinity of seawater is relatively uniform, around 28 - 30 $^{o}/_{oo}$. The changes of water salinity affect the growth cycles of species in the region, including clam species [1]. The ecological temperature threshold of clam species ranges from 13 - 40^{o}C and grows best at temperatures from 26^{o}C [15]. A clam has lower growth when the temperature remains high for a long time. Through the PRA survey in 2010 of MCD, most people said that the temperature increased considerably in recent years. For example, in 2010, a heat wave reached between 37 - 40^{o}C continuously for about 20 days and the lack of rainfall increased salinity. Consequently, this caused several sudden clam deaths. This suggests that temperatures will tend to be higher in hot seasons and affect the overall operation of the clam farming community.

3. Methodology

Similar to environmental economics, climate change economics considers climate change as "market failures" to value the economic losses due to the climatic changing. According to the hazard damage estimate methodology of the International Center for Geo-hazards (ICG), the potential damage due to a natural hazard could be estimated with below formula:

$$R = H*V*E$$

- R: Risk (potential loss for the element at risk)

- H: Hazard (temporal probability of a threat)

- V: Vulnerability (physical vulnerability of human, environment)

- E: value of vulnerable Elements

Hazard and vulnerability are all quantified in terms of temporal probabilities, signifying their respective uncertainties. Hazard is defined as the temporal probability of an undesirable event affecting the element at risk. V is the degree of damage or probability for damage for the element at risk given that the hazard happens, varying from a scale of 0 (no loss) to 1 (total loss) and E is the utility of damage or the maximum expected loss given that a hazard happens. A vulnerability has two perspectives. The social vulnerability, or the "capacity of a society to cope with hazardous events" and the physical vulnerability, or the "degree of expected loss in a system from a specific threat", quantified between 0 (no loss) and 1 (total loss). Vulnerable categories include people, structures, lifelines, infrastructure, vehicles, and the environment [11]. The model in this case study addresses the physical vulnerability quantitatively. This equation should be looked at as a convolution of three functions or a summation over all possible scenarios. In this case, a scenario-based approach has been adopted.

In practical situations, one must make a number of assumptions and simplifications. For hazard term H, climate change scenarios were considered based on the IPCC scenarios. The probabilities are completely arbitrary but should add up to one cover all scenarios. The Event Tree Analysis was adopted to assume the probability of each scenario.

An event tree analysis (ETA) is an analysis technique for identifying and evaluating the sequence of events in a potential accident scenario following the occurrence of an initiating event. ETA utilizes a visual logic tree structure known as an event tree. The objective of

ETA is to determine whether the initiating event will develop into a serious mishap or if the event is sufficiently controlled by the safety systems and procedures implemented in the system design. An ETA can result in many possible outcomes from a single initiating event, and it provides the capability to obtain a probability for each outcome [6].

In all models, parameters are more or less uncertain [13]. The modeler is likely to be unsure of their current values and to be even more uncertain about their future values. The principle of a sensitivity analysis is very simple: change the model and observe the behavior [13]. Due to the uncertainty of climate change scenario, a sensitivity analysis has been done with two metrics V and H to be varied.

This study conducted site visits, discussions with the local people and a literature review to collect information. Based on the typical physical characteristic and growth condition of clam, some assumption of climate change scenarios were made related to the clam farming environment. Below are some climate change factors that may affect the clam culture:

(i) The increase in temperature leads to the increase of sea surface temperature (Due to the limitation of climate change project models, it is assumed that the increase of sea surface temperature are equivalent to the increase of air temperature);

(ii) Changes in salinity due to salt intrusion, heat wave or extreme rain, flood;

(iii) Hurricanes, tropical storms

(iv) The concentration of CO_2 in the air increases leading to the increase of the absorption of CO_2 in the oceans. This makes the pH of saltwater decrease and shellfish may have a harder time building their shells (NOAA)

Among them, the factor number (ii) and (iv) happen gradually and it is not easy to estimate the concrete effect. Moreover, the impact of storm; flood to aquaculture is very large; this paper concentrated only on the impact of temperature increase to clams culture in Giao Xuan commune. The below scheme shows the overall methodology and approach of this research:

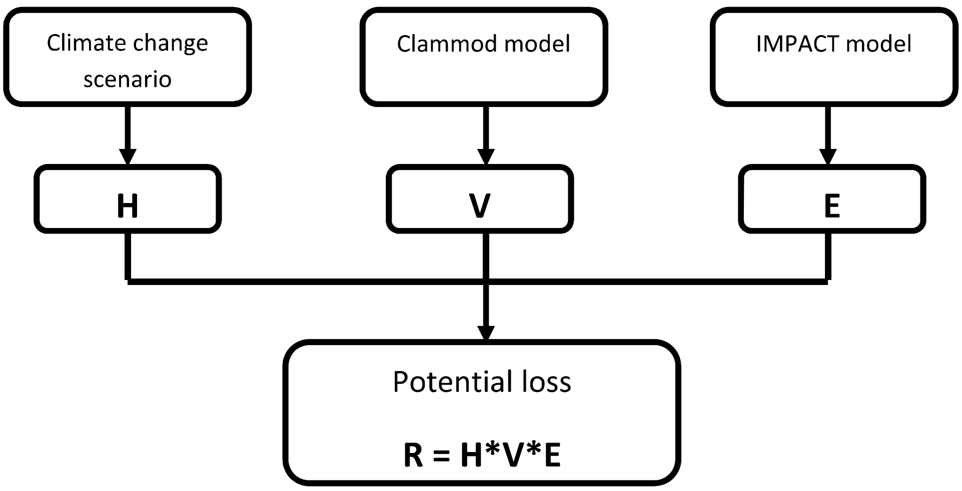

Figure 2: Approach scheme to estimate the loss due to climate change to aquaculture

Estimating the climate change impacts in clam culture in Giao Xuan commune

Table 2 shows temperature scenario for North Delta of Vietnam in 2030, 2050, and 2090.

Table 2. Temperature scenario for North Delta of Vietnam in 2030, 2050, and 2090

Year	Scenario	High impact climate future		Least change climate future	
		Temperature change	Number of models have the same result	Temperature change	Number of models have the same result
2030	A1B - medium emissions	+1.1^{o}C	9/30	+0.9^{o}C	12/18
	B1 - low emissions	+0.9^{o}C	9/17	0.3^{o}C	4/17
	A2 - high emission	+0.8^{o}C	7/15	0.4^{o}C	2/15
	RCP 4.5 - low	+0.9^{o}C	2/34	+1.1^{o}C	23/34
	RCP 8.5 - very high	+1.1^{o}C	18/30	-	-
2050	A1B - medium emissions	+2.2^{o}C	16/30	-	-
	B1 - low emissions	-	-	-	-
	A2 - high emission	-	-	-	-
	RCP 4.5 - low	+1.9^{o}C	11/31	+1^{o}C	11/31
	RCP 8.5 - very high	+2.2^{o}C	16/30	+1.3^{o}C	2/30
2090	A1B - medium emissions	+3.5^{o}C	3/18	+2.5^{o}C	5/18
	B1 - low emissions	+1.9^{o}C	6/17	+1.3^{o}C	3/17
	A2 - high emission	+3.6^{o}C	7/15	+2.5^{o}C	2/15
	RCP 4.5 - low	+3.6^{o}C	1/36	+1.1^{o}C	4/36
	RCP 8.5 - very high	+3.9^{o}C	6/34	+3^{o}C	1/34

Source: High resolution climate projecting for Vietnam, 2013

A simplification (using Event Tree Analysis) has been made for those above scenarios as following:

Table 3. Simplification of scenarios with their probability for North Delta of Vietnam in 2030, 2050, and 2090 based on the result of High resolution climate projecting in Vietnam

Year	Scenario	Temperature change	Probability
2030	1	<1^{o}C	0.4
	2	>1^{o}C	0.6
2050	1	<2^{o}C	0.35
	2	>2^{o}C	0.65
2090	1	<1.5^{o}C	0.25
	2	1.5^{o}C - 3^{o}C	0.25
	3	>3^{o}C	0.5

Seasonality in the clam farming activities are affected by climate change impacts in practice as below:

Table 4. Clam aquaculture seasonal calendar in Giao Xuan commune with climate change

<table>
<tr><td>Month (lunar calendar)</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>Jun</td><td>Jul</td><td>Aug</td><td>Sep</td><td>Oct</td><td>Nov</td><td>Dec</td></tr>
<tr><td rowspan="2">Farming season</td><td></td><td></td><td></td><td>Preparation breeds</td><td colspan="2">Seedling at small size</td><td colspan="3">Seedling at middle size</td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Aquaculture process</td></tr>
<tr><td>The phenomenon of natural disaster</td><td colspan="3">phenomena frost</td><td></td><td colspan="2">Hottest</td><td colspan="3">storm floods</td><td></td><td colspan="2">Coldest</td></tr>
<tr><td>Busy time</td><td colspan="4">Improve culture beach</td><td colspan="5">clam seed mining</td><td></td><td></td><td></td></tr>
</table>

Source: PRA group meeting in Giao Xuan [1]

The table No. 4 above shows that extreme weather phenomena occurs mainly during the seedling process: from April to seedling the small size (May - June) and seedling at the middle size (July - September), which is also the most fragile time for clam culture farming. Therefore, the time is considered is summer with the average temperature is 28 - 29°C.

The analysis of the relationship between clam growth and temperature which was originally developed and adopted for the northern Adriatic Lagoon (where has the same clam species - Meretrix lyrata) was a foundation for this research. ClamMod is a bioenergetic model that reproduces individual growth of clams as a function of water temperature, seston concentration and energy content of the seston [15]. According to the model, if the amount of energy potentially ingested through filtration is larger than the capability of an individual to metabolize it, the growth rate is limited by metabolic processes within the clam and varies with clam size and temperature, regardless of food availability. Conversely, if the energy potentially obtained from ingested food is less than what a clam would be able to use, there is a food limitation, and growth depends on the concentration and energy content of the seston. The rates of metabolic processes increase exponentially as the temperature increases from low values up to an optimum level and then decrease as temperature reaches an upper limit. Physiological thermal limits resulting from the interplay between anabolic and catabolic processes change with clam size, but optimal conditions for clam growth are around 25°C (Fig. 3), whereas around 30°C catabolic and anabolic processes equilibrate and growth stops [15].

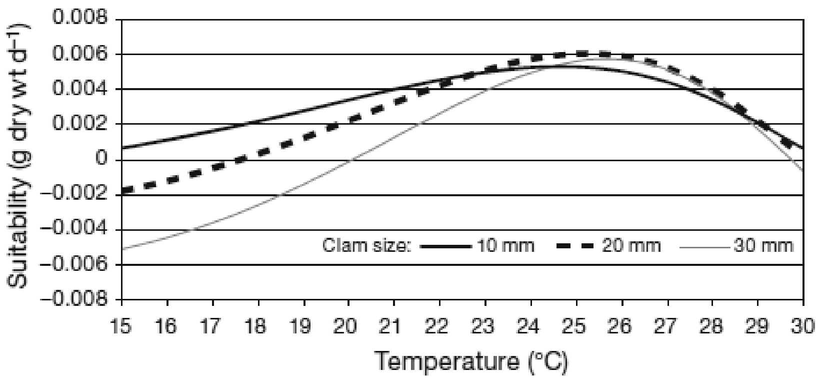

Figure 3: Habitat suitability for clam growth as a function of water temperature and clam size [15]

Based on the above result, if average temperature increase 1°C (2030), clam growth would decline by approximately 20%. For scenario 2 (average temperature increases more than 1°C), the potential loss was assumed to be 30%. The potential loss of clam culture due to climate change in 2030 could be estimated as below:

R = (H1*V1 + H2*V2)*E

Among them, R = potential loss

H1 = probability of scenario 1

V1 = vulnerability in scenario 1

H2 = probability of scenario 2

V2 = vulnerability in scenario 2

E = value of clam culture (assumed to be unchanged by time)

Then: R = (0.4*0.2 + 0.6*0.3)*E

= 0.26E

= 26% E

In other words, the value of clam culture in Giao Xuan 2030 would likely reduce by 26% compared to the potential value.

Similarly, other scenarios and their probability together with the potential loss of clam culture in Giao Xuan commune were assumed and identified as following:

To complete the picture, the E value could be calculated based on the result of International Food Policy Research Institute - IFPRI's IMPACT model applied by [4] to global analysis of fisheries and the economy. IMPACT model is a global simulation model to examine food supply, demand, trade, prices and food security and is the only available model that incorporates a globally consistent set of elasticity parameters regarding the mollusk fisheries and aquaculture [4]. Under the baseline scenario of above-mentioned simulation of Delgado, the price and production of clam culture in this area could be estimated for those years assuming that the change in the price of clam is equivalent to mollusks in general and the annual growth rate of Vietnamese clam is equal to Southeast Asia's aquaculture. The growth rate of production for the period 2010 until 2090 is also assumed not to change compared to the period until 2020.

Table 5. Potential loss of clam culture in Giao Xuan in 2030, 2050, and 2090

Scenario	Hazard probability	Vulnerability of clam due to climate change	Potential loss
2030			**26%**
Scenario 1 (t increase< 1°C)	0.40	0.2	
Scenario 2 (t increase> 1°C)	0.60	0.3	
2050			**36,5%**
Scenario 1 (t increase< 2°C)	0.35	0.3	
Scenario 2 (t increase> 2°C)	0.65	0.4	
2090			**57,5%**
Scenario 1 (t increase < 1,5°C)	0.25	0.4	
Scenario 2 (t increase 1,5 - 3°C)	0.25	0.5	
Scenario 3 (t increase > 3°C)	0.50	0.7	

Belowis the estimation of E value:

Year	Price (USD)	Production (000 ton)	E value (000 USD)
2010	1.00	6,950	6,950
2030	1.04	9,178	9,545
2050	1.08	12,120	13,109
2090	1.17	21,136	24,726

With the above potential loss, the risk of clam in Giao Xuam commune due to climate change could be estimated at about 2.5 million dollar in 2030 and this number will increase to 4.8 and 14.2 million dollars in 2050 and 2090 respectively.

4. Discussion and conclusion

Clam aquaculture is very sensitive to water salinity, weather temperature and natural foods. These indicators are much more affected by climate and environmental changes. Therefore, the potential loss of clam culture due to climate change in Giao Xuan commune is high (2030: 26% loss, 2050: 36,5% loss and 2090: more than 50% loss). The risk of clam aquaculture in Giao Xuam commune due to climate change could be estimated at about 2.5 million dollars in 2030 and this number will increase to

4.8 and 14.2 million dollars in 2050 and 2090, respectively. This will affect the community in this area as clam farming is the main livelihood in this commune.

In practice, local farmers apply "autonomous" adaptation as they make practical changes such as like adjusting their seasonal calendar, changing the farming area (with deeper water to help clam can suffer from heat waves), improving the pond for seedling (not in the intertidal area) to reduce the exposure of seeding clam or to use sun-proof nets for aquaculture in the hot temperature. These are only temporary and costly solutions to help communities in coping with the climate change impacts. Climate change will reduce the return of clam farmers as they have to invest more for infrastructure. That is the reason why scientists, non-government organizations together with the policy makers should cooperate to find out the best solution with a view to minimize the loss and improve the livelihood for coastal community, especially the poor who are the most vulnerable to natural hazards.

To increase livelihood resilience and reduce vulnerability, it is critical to improve the adaptive capacity, raise awareness for local community groups on climate change impacts, find conflicts solutions and linkages with the ecological systems resilience, along with the policy and institutional development process that enhance the local governance of the coastal resources.

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SOIL EROSION IN DA RIVER BASIN AND SEDIMENTATION IN HOA BINH RESERVOIR

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Abstract

Da River is a main tributary of the Red river in the Northwestern part of Vietnam. It has the highest hydro-power potential in Vietnam. There are three key hydro-power plants built on the main stream of the river: Hoa Binh, Son La and Lai Chau. These three hydro-power plants have been contributing greatly to the power generation of Vietnam and flood control for Hanoi capital and the downstream. Because of the erosion process, Da is a sediment-laden river. Erosion has been causing severe deposition in the reservoirs. This paper presents the calculation of sediment yield, maps the suspended sediment module of Da river basin, estimate the lateral sediment flow of Hoa Binh reservoir, impacts of Son La reservoir and Lai Chau reservoir located at the upstream on the sedimentation process in Hoa Binh reservoir.

Keywords: Soil erosion; Sediment; Da river; Hoa Binh reservoir.

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1. Introduction

River discharge and sediment load are affected by various environmental changes within a drainage basin in an integrated way [11, 13]. In addition, human activities such as dam construction and agricultural irrigation, has seriously changed the hydrological cycle in most river basins. Streamflow or sediment load characteristics of a watershed are closely related to the geology, topography, climate, land use/vegetative cover and human activities within the basin. While geologic and topographic variables are fixed in the short term, long-term changes occur in climatic conditions [4, 6]. On the other hand, human activities or vegetative cover changes would produce abrupt alterations in streamflow, erosion process and sediment load [5, 11, 12]. All environmental changes play an important role in altering the surface flow and sediment yield [3, 16]. Average elevation in the whole river basin and in the territory of Vietnam is 1,130 m MSL and 916.5 m MSL respectively.

The river basin is in tropical-monsoon climate region with pronounced wet and dry seasons. It is cold and dry in the winter, hot and wet in the summer. Mean annual precipitation is about 1,600 mm. Typically, 85% of the rainfall falls during the months of the rainy season. Mean annual runoff of the Da river at Hoa Binh hydrological station which is around 55.7 cu.km, equivalent to water discharge of 1,770 m^3/s. Mean annual sediment load is 72.3 million tons, resulting in an average suspended sediment concentration of 1,310g/m3. Sediment is mainly fine sand with D50 ranging from 0.025 - 0.040 mm and D90 ranging from 0.20 - 0.25 mm. The duration of a flood event is generally 4 - 7 days. Distribution of water and sediment within one year is extremely uneven with 90% of annual water volume