

SEDIMENT DYNAMIC PROCESS OF TIRUMALAIRAJAN ESTUARY, EAST COAST OF INDIA

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Abstract: In order to investigate the sediment dynamics behavior of Tirumalairajan river estuary characterized by sediment sampling were undertaken to obtain data sets of grain size parameters in monsoon and summer seasons (2009). The mean grain size increased, sorting improved, and skewness became more positive and leptokurtic to very leptokurtic nature in both seasons. The spatial distribution indicates majority of sample fall in sand category in both seasons. Based on the CM pattern the sediment fall in rolling and suspension field. The sediments may be derived from offshore and catchment area deposits of the clay and silt, and evidence was found to suggest that these deposits are being eroded by tidal currents.

Keywords: Grain size analysis, estuary sediments, Tirumalairajan, east coast.

1. INTRODUCTION

Textural characteristics of estuarine sediments are strongly influenced by several factors, including source area composition of adjacent lands, climate, length and energy of sediment transport, redox conditions in the depositional environments (Bhatia & Cook, 1986; Fralick & Kronberg, 1997, Anithamary et al., 2011 and Venkatramanan et al., 2011). Numerous studies have analyzed grain-size properties which can suggest sources and hydrodynamic conditions of marine sediments (Carranza-Edwards et al., 2005). Moreover, spatial variations in sediment composition can help to determine present estuary environment conditions. Statistical methods are usually employed to simplify the necessary comparisons among samples and quantify the observed differences (Poppe et al., 2004). Statistical methods are usually employed to simplify the necessary comparisons among samples and quantify the observed differences. The two statistical methods most commonly used by sedimentologists to describe particle distributions are mathematical moments (Krumbein & Pettijohn, 1938) and inclusive graphics (Folk, 1974). In the present investigation the grain

size parameters are used to interpret sediment movement in Tirumalairajan river mouth.

2. DESCRIPTION OF STUDY AREA

The study area (Fig.1) Tirumalairajan estuary is tributary of major river Cauvery in the central part of Tamilnadu. It is located between latitudes 10°52' to 10°53' N and longitudes 79°48' to 79°51' E in east coast of India. The region is covered by the Survey of India topographic sheets 58M/13 and 16. Figure.1. shows the location of the study area in India and in particular to Tamil Nadu. Tirumalairajan river generally flow from west towards east and the pattern is mainly sub parallel. The influence of tide was noticed upto 8-10 km in the upstream direction. The catchment area comprises of a terrain of granite, charnockite and gneisses. The river then flows through recent alluvium deposits which are composed of clays and silts before it joins to the sea. The mouth of the estuary is always open to the sea. There being no complete closure of the bar and hence regarded as a true bar built estuary with semidiurnal nature.

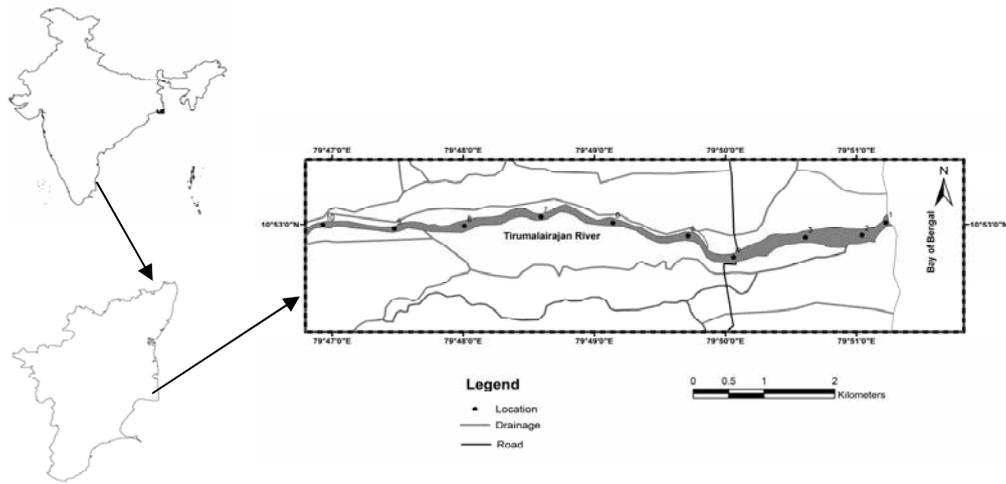
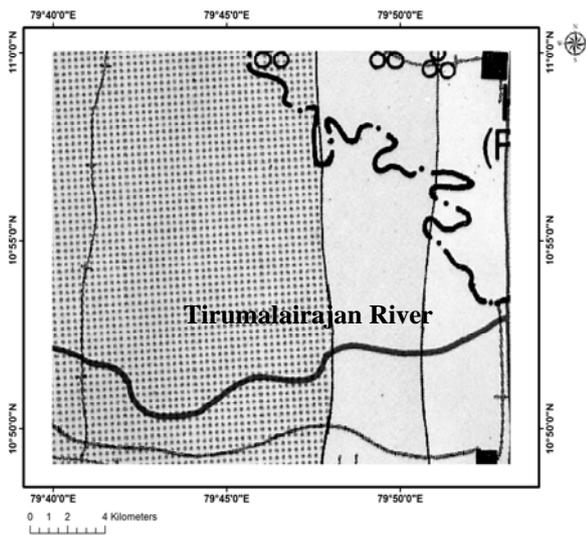


Figure.1. Location Map of the study area

The geology of the present study (Fig. 2) mainly comprises of quaternary sediments increases south of Coleroon River. These sediments have been delineated as alluvial plain deposit of the Cauvery River and its distributaries, narrow fluvio-marine deltaic plain deposits and marine coastal plain deposits (east coast formation).

flood basin, point bar, channel bar and palaeo channels with admixtures of sand, silt and clay. The deltaic plain includes palaeo tidal flats, with clays and sands and sand ridges or gray brown sand. The marine coastal plains include beach, tidal flats, salt marsh, mangrove swamps, deposits of sand and clay. The mouth of the river comprises alluvium deposits which are composed of clays and silts. The general stratigraphy succession of the study area is divided into three formations such as, recent to sub-recent, pliocene and mio-pliocene formations.

The climate of the area is generally hot, semidry, and tropical. March to June is the hottest months and December to February are the cooler months of the year. The major portion of the annual rainfall is received during the Northeast monsoon period recorded during October to December. A very meager amount of rainfall is received during the summer, January to April and the remaining precipitation is received during the southwest monsoon period from June to September.



Source-Geological Survey of India (GSI)

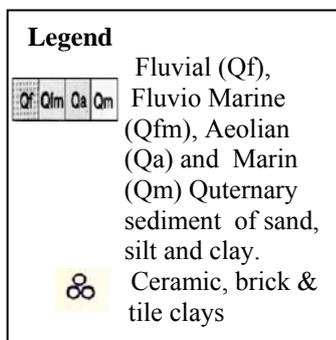


Figure 2. Geology of the study area.
The fluvial deposits comprise flood plain,

3. MATERIAL AND METHODS

A total of twenty sediment samples were collected representing monsoon and summer 2009 covering the estuarine, mouth and freshwater zone of Tirumalairajan river. The sediment samples were collected by using a Van Veen grab sampler on board hired fishing trawler. Sub-sampling of the sediments was done by taking upper 5cm of the sample from the grab with the help of plastic spatula. Sediment samples were then frozen at 4°C prior to analysis. Station locations were obtained by the Global positioning system (GPS). Sediment samples were then oven dried at 60°C for further analysis. Sieving

technique is applied to separate the grains of various size classes (Ingram, 1970).

Sieving was carried out in ASTM sieve at $1/4 \phi$ intervals for about 20 minute in Digital sieve shaker (Retsch AS 200). Pipette analysis was carried out to compute sand, silt and clay fractions. This basic data i.e. weight percentage frequency data is converted into cumulative weight percentage data, served as basic tool for the generation of other statistical parameters (Table 1a and b, Table. 2a and b) using USGS GSSTAT program (Poppe et al., 2004) described herein generates statistics to characterize sediment grain-size distributions and can extrapolate the fine-grained end of the particle distribution. It is written in Microsoft Visual Basic 6.0 and provides a window to facilitate program execution. The input for the sediment fractions is weight percentages in whole-phi notation (Krumbein, 1934; Inman, 1952).

Table 1a. Graphic measure from the grain-size analysis of the samples (Monsoon)

<i>Station</i>	<i>Median</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Skewness</i>	<i>Kurtosis</i>
1	1.93	1.98	0.68	0.19	1.12
2	1.62	1.71	0.64	0.22	1.37
3	1.37	1.37	0.88	0.1	1.13
4	1.24	1.27	0.89	0.15	1.02
5	1.15	1.12	0.74	0.05	1.03
6	0.72	1.08	1.08	0.57	1.02
7	1.41	1.4	0.81	0.05	1.13
8	2.03	1.79	1.05	-0.21	0.91
9	1.92	1.98	1.04	0.12	1.09
10	3.35	3.41	0.31	0.28	0.79
Min.	0.72	1.08	0.31	-0.21	0.79
Max.	3.35	3.41	1.08	0.57	1.37
Aver	1.73	1.8	0.79	0.15	1.06

Table 1b. Percentage of sand, silt and clay (Monsoon)

<i>Station</i>	<i>Sand %</i>	<i>Silt %</i>	<i>Clay %</i>
1	95.35	4.32	0.23
2	97.28	6.52	1.65
3	98.62	7.68	0.54
4	95.32	6.3	1.23
5	97.05	4.2	0.68
6	95.73	4.82	0.34
7	96.82	2.46	4.52
8	97.46	5.78	0.54
9	97.23	3.33	0.32
10	98.32	1.06	3.68
Min.	95.32	1.06	0.32
Max.	98.62	7.68	4.52
Aver.	96.92	4.60	1.42

Table 2a. Graphic measure from the grain-size analysis of the samples (Summer)

<i>Station</i>	<i>Median</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Skewness</i>	<i>Kurtosis</i>
1	1.5	1.5	0.99	0.13	1.11
2	1.44	1.45	0.86	0.08	1.1
3	2.5	2.35	1.08	-0.21	1.1
4	1.99	2.1	1.06	0.14	1.03
5	1.6	1.7	0.91	0.19	1.32
6	2.41	2.35	0.76	-0.04	1.5
7	1.2	1.22	0.84	0.13	1.02
8	1.46	1.44	0.64	0.14	1.41
9	1.82	1.82	1.23	0.12	1.62
10	2.35	2.41	0.31	0.38	0.79
Min.	1.2	1.22	0.31	-0.21	0.79
Max.	2.5	2.41	1.23	0.38	1.62
Aver.	1.83	1.93	0.85	0.09	1.20

Table 2b. Percentage of sand, silt and clay (Monsoon)

<i>Station</i>	<i>Sand %</i>	<i>Silt %</i>	<i>Clay %</i>
1	95.35	2.65	0.25
2	97.28	5.68	1.68
3	98.62	20.65	6.38
4	95.32	17.64	7.36
5	97.05	3.66	0.67
6	95.73	5.69	0.42
7	96.82	0.11	1.68
8	97.46	0.34	1.68
9	64.58	42.36	4.69
10	86.32	36.25	5.68
Min.	64.58	0.11	0.42
Max.	98.62	42.36	7.36
Aver.	90.64	14.74	3.06

4. RESULTS AND DISCUSSION

4.1. Statistical analysis

Median value of the particles by weight is coarser to it and half is fine. During monsoon obtained values range from 0.72 to 3.35 ϕ and summer ranged from 1.2 to 2.5 ϕ . These values, in general, show the dominance of medium to fine sand size sediments. Phi mean size (Mz) is a measure of central tendency, which is calculated by the formula $\phi 16 + \phi 50 + \phi 83 / 3$. The occurrence of lower phi mean size noted during the monsoon at upstream direction indicates the removal of fines leading the relatively coarser materials in that location. The higher phi mean size noted during summer at station - 3, indicated less influence of freshwater flow and relatively calm nature of the coast which favour the settlement of fines and makes the phi mean size to higher side. Standard

deviation is the measure of sorting or uniformity of particles size distribution and it is calculated by the formula $\phi_{84} - \phi_{16} / 4 + \phi_{95} - \phi_5 / 6.6$.

The values obtained range from 1.08 to 3.41(monsoon season, Fig. 3A) and the observed minimum and maximum values ranged from 1.22 to 2.41 ϕ (summer season, Fig. 3B) most of samples are moderately to poorly sorted during monsoon and

summer respectively. The inclusive standard deviation value was lower at mouth and freshwater zone when compared with the estuary. This indicates the influence of the mean grain size on the sorting nature of the sediments. A relatively better sorting values observed during monsoon seasons indicates the removal of finer material leading to a better sorting of sediments.

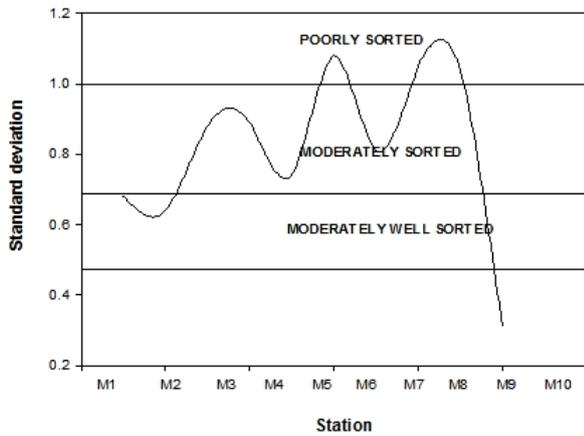


Figure 3A. Standard deviation during monsoon season

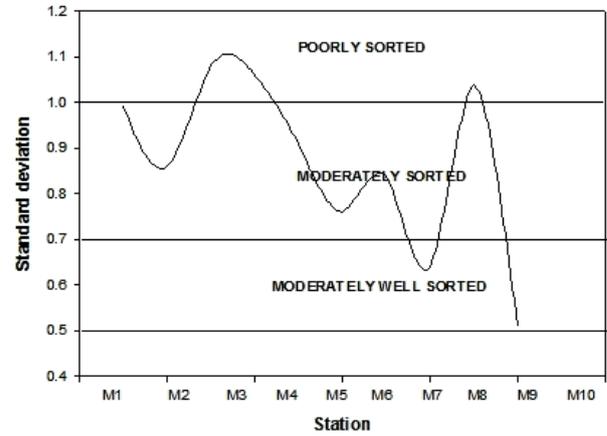


Figure 3B. Standard deviation during summer season

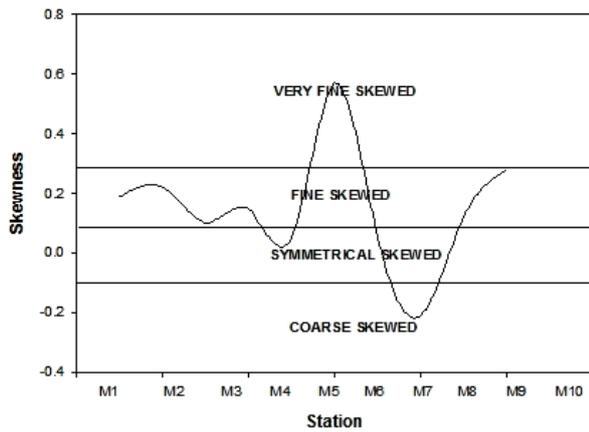


Figure 4A. Skewness during monsoon season

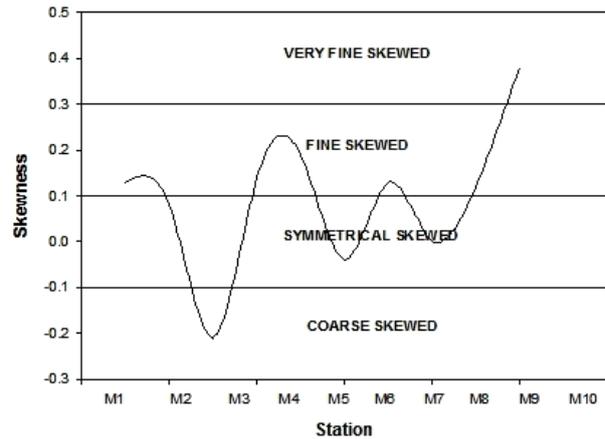


Figure 4B. Skewness during summer season

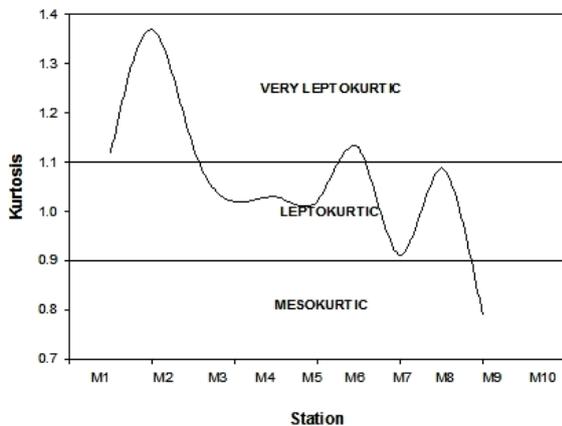


Figure 5A. Kurtosis during monsoon season

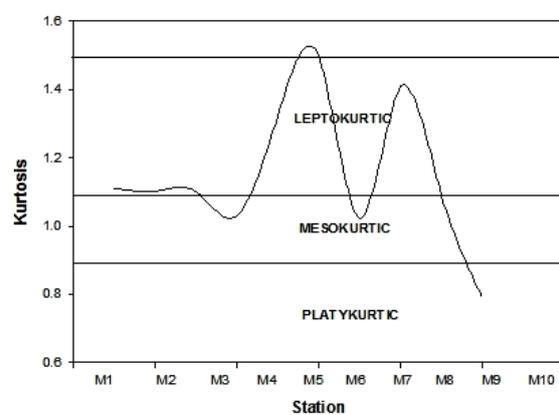


Figure 5B. Kurtosis during summer season

The mean size of the sediments is mainly derived from the catchment of the river and also controlled by the climatic condition of the present study. The skewness measures the systematic of the distribution or predominance of coarse or fine-sediments. It is calculated by the formula $\phi 84 + \phi 16 - 2 \phi 50 / (\phi 84 - \phi 16) + \phi 95 + \phi 5 - 2 \phi 50 / (\phi 95 - 2 \phi 5)$. The negative value denotes coarse-skewed material, whereas, the positive value represents more material in the fine-tail i.e. fine skewed. During monsoon (Fig. 4A) and summer (Fig. 4B) the skewness value ranged from -0.21 to +0.57 ϕ and -0.21 to 0.38 ϕ it indicates the, fine to very fine skewed and some of them coarse skewed category. A higher skewness value was observed during summer at downstream direction. The skewness value reveals that most of sediments during study period are nearly fine to very fine skewed. This indicates the presence of considerable amount of finer particles and also estuary conditions are more conducive for the settlement of fines. A lower skewness value was observed during monsoon mouth and freshwater zone. It indicates the sediments are nearly symmetrical nature. It may be due to the mixing of two populations from the different sources. In general, the sediments show the tendency of more material in fine tail. The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. If the tails are better sorted than the central portions, then it is termed as platykurtic, whereas, leptokurtic, if the central portion is better sorted. If both are equally sorted then mesokurtic condition prevails. During the monsoon and summer the values obtained ranges from 0.79 to 1.37 ϕ and 0.79 to 1.62 ϕ respectively. However, there is a dominance of mesokurtic to leptokurtic due to the high fraction of fine-grained sediments (Fig. 5A and B).

This indicates the concentration of one dominant and other subordinate population. The

dominant of fine mode give rise to the leptokurtic nature. The statistical nature of the sediments indicates, deposition of the sediments largely derived from the source area of the river and its tributaries. The major minerals of the study area are quartz and feldspar. The geology and climatic condition of the present study are favor for the deposition of sediments in Tirumalairajan river estuary.

4.3. Spatial distribution

Sedimentological datasets are typically large and compiled into tables or databases, but pure numerical information can be difficult to understand and interpret. Thus, scientists commonly use graphical representations to reduce complexities, recognize trends and patterns in the data, and develop hypotheses. Of the graphical techniques, one of the most common methods used by sedimentologists is to plot the basic gravel, sand, silt, and clay percentages on equilateral triangular diagrams. This means of presenting data is simple and facilitates rapid classification of sediments and comparison of samples (Poppe and Eliason, 2007). The study reveals that the estuarine sediments of Tirumalairajan river fall in the maximum sand percentage observed in mouth of the river it is due to the littoral current activities and silt and clay percent in the upper course of the river during monsoon season (Fig. 6A, B and C).

During summer season most of the samples fall in sand percent in the both part upper and lower part of the estuary. Silt and clay deposited in the upper course of the river (Fig.7A, B and C). This may be due to the calm nature and non-linear sand-mud mixing under the complex hydrodynamic condition.

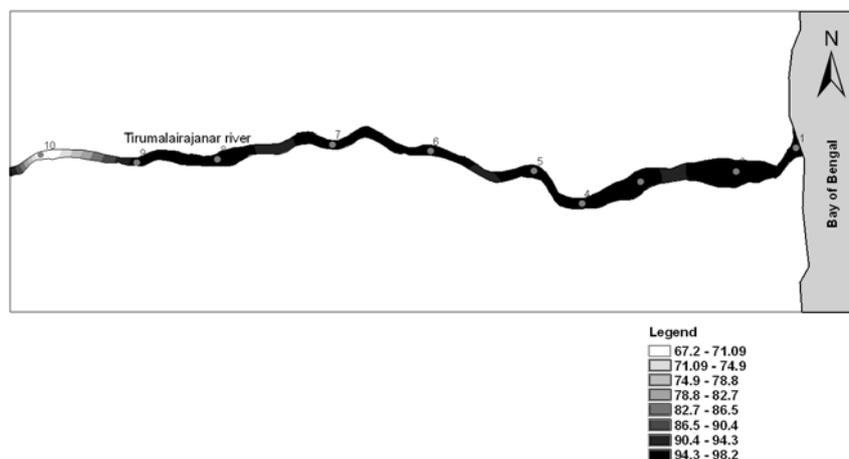


Figure 6A. Spatial distribution of sand (monsoon)

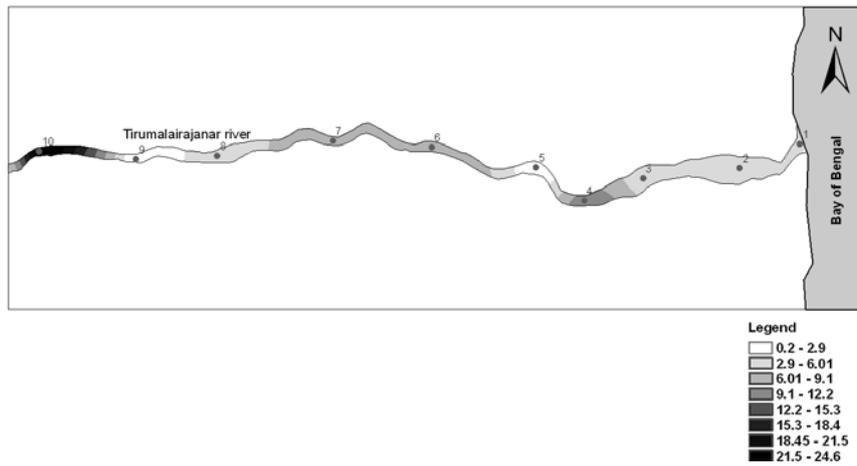


Figure 6B. Spatial distribution of silt (monsoon)

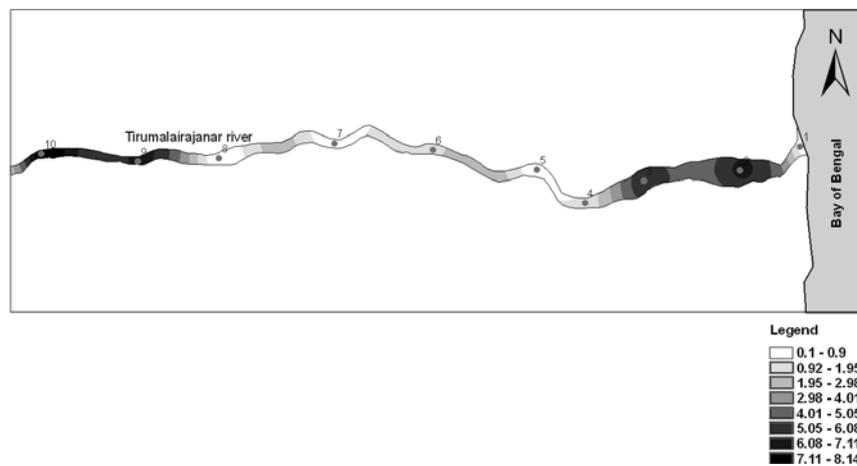


Figure 6C. Spatial distribution of clay (monsoon)

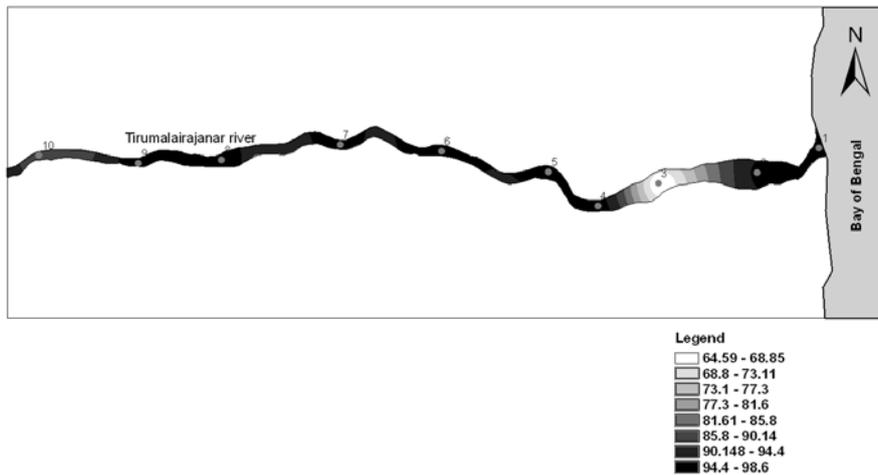


Figure 7A. Spatial distribution of sand (summer)

The spatial distribution map shows the fine grain nature of the sediments were present in estuary region. It could be attributed to low fluvial discharge and a better mixing of saline and freshwater that facilitates flocculation and coagulation resulting in settling of fine particles (Venkatramanan et al., 2011).

4.4. Bivariate plot

Certain plots are considered significance for the interpretation of depositional environment (Moiola & Weiser, 1968) has also been attempted. The plot between mean vs standard deviation is considered as an effective tool to differentiate between beach and river sands.

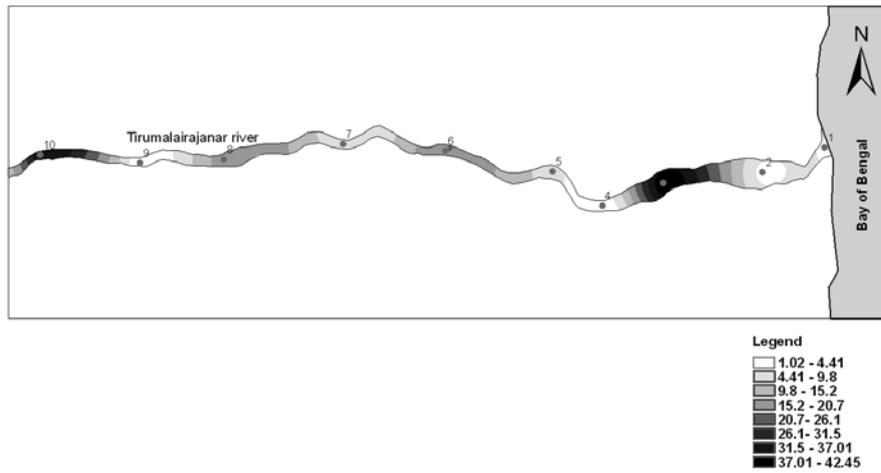


Figure 7B. Spatial distribution of silt (summer)

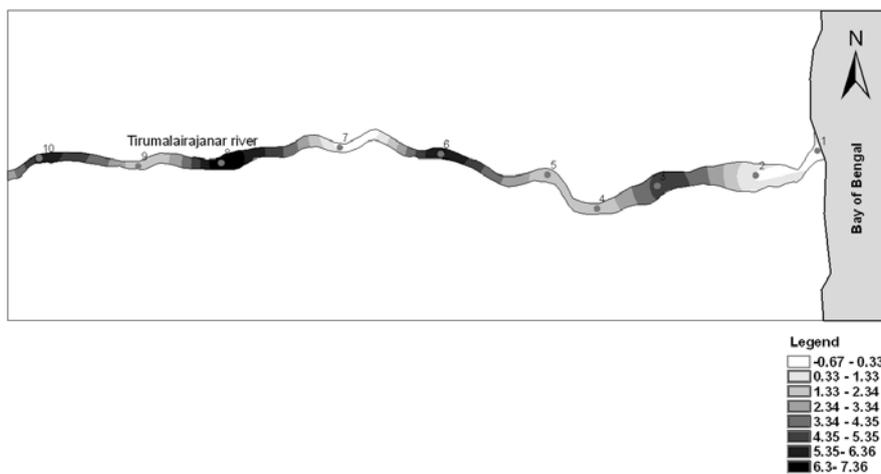


Figure 7C. Spatial distribution of clay (summer)

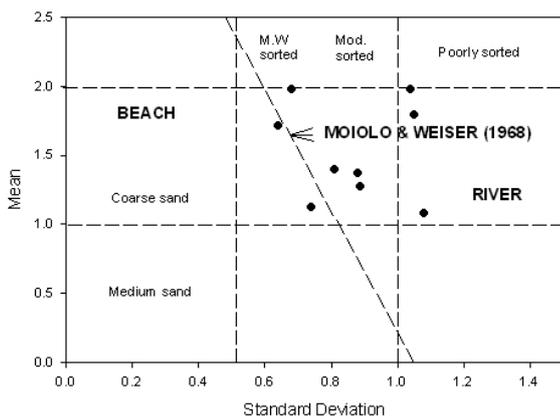


Figure 8A. Bivariate plot of mean Vs standard deviation (monsoon)

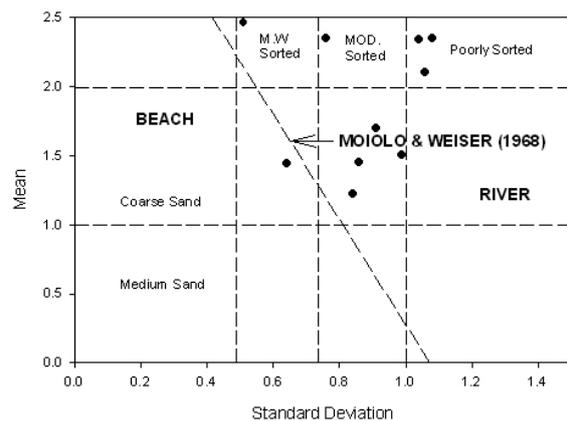


Figure 8B. Bivariate plot of mean Vs standard deviation (summer)

Accordingly, the present plot indicates that the sediment samples fall in river influence during monsoon (Fig. 8A and B) and summer (Fig. 9A and B). Moiola & Weiser (1968) considered the plot between standard deviation vs skewness is great

significance to differentiate between beach and river environments. The trends of present sediments are clearly indicative of river influence during both monsoon and summer seasons.

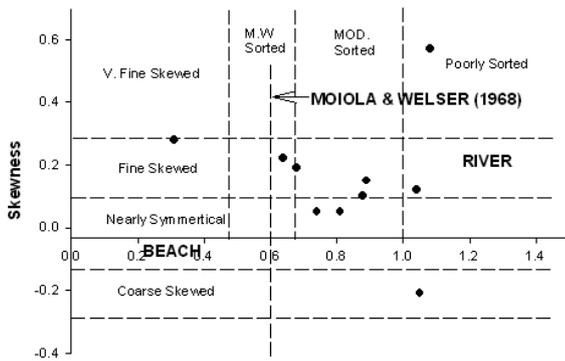


Figure 9A. Bivariate plot of standard deviation Vs skewness (monsoon)

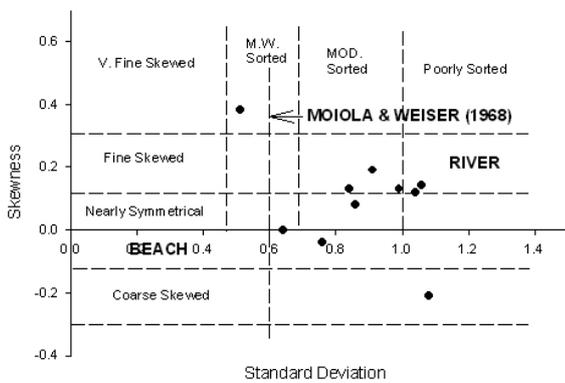


Figure 9B. Bivariate plot of standard deviation Vs skewness (summer)

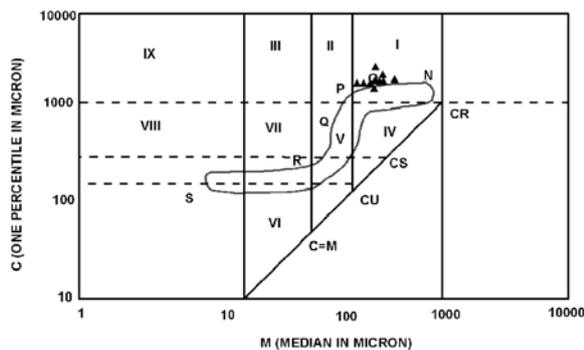


Figure 10A. CM pattern during monsoon season

4.5. Hydrodynamic Condition (CM-Pattern)

Passega (1957) introduced C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments. It is a relationship of 'C' i.e. coarser one percentile value in micron and 'M' i.e. median value in micron on log-probability scale. The present plot is made and interpreted following Passega (1957, 1964) and Passega & Byramjee (1969). Accordingly, monsoon season most of the

samples fall in N-O region of sector I, which denotes rolled sediments with little or no suspension (Fig. 10A). Summer season most of the samples fall in P-O region of sector I, which indicate rolling and suspension field (Fig. 10B). It is reveal that sediments were carried by suspension and the decrease in velocity and depth of flow tends to drop some of the coarser material along with some matrix.

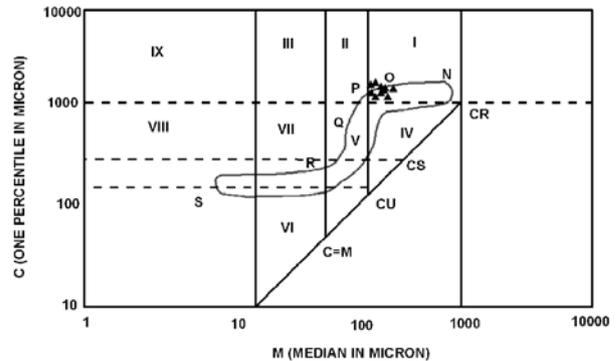


Figure 10B. CM pattern during summer season

5. CONCLUSIONS

This study describes the sedimentary properties of surface sediments in Tirumalairajan river estuary, their major inputs and their main transport and depositional processes and main hydrodynamic of the Cauvery river. Our results indicate that the grain size analysis of twenty sediment samples (monsoon and summer). The mean value indicates the dominance of medium sand size particles. The sediments, in general, show moderate sorting and are dominantly fine to very fine-skewed in nature. In majority of the cases, both peak and tails are equally sorted giving rise to leptokurtic to platykurtic condition. Spatial distribution pattern, both seasons shows the all the sediments are coarse to fine sand in nature. The sediments are mostly rolled and deposited by traction currents, however, a few samples showing suspension mode is because of more quantity of fine grained material during monsoon and summer seasons. Geology and climatic conditions play a vital role to control the sediment dynamic nature of the Tirumalairajan river estuary.

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