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Laser Diffraction Analysis Application on the Grain Size Analysis of Mati River Delta Sediments (Albania)

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Abstract: ***The source of Mati River is located in the Bulqiza district (North of Albania), while its delta is situated near to Rodoni Gulf. It has a length of 115 km and a surface basin is 2450 km^2, including two contributors as Mati and Fani branches. Laser Diffraction Analysis was applied for the grain size analysis of beach sediments of Mati river delta. The measurements were carried out with Malvern instrument while the dataset were generated by performing Mastersizer 2000 software. This research aim is presenting the grain-size distribution, depositional processes, hydrodynamic condition, mechanism of sedimentation and depositional environments. The bivariate analyses, linear discriminant functions, were used for twenty six samples from the shoreline of Mati river delta. The results of grain size parameter reveal that samples of the study area are mostly medium sand followed by fine sand, moderately well sorted, symmetrical nature and mesokurtic to leptokurtic distribution. The analysis of linear discriminate function indicates that sediments were reworked by Aeolian or beach processes, under the environment of shallow marine and by fluvial deposits.***

Keywords: Bivariate plots, Coastline, Laser Diffraction, Linear discriminant functions

1. Introduction

The aim of this paper is determining of the granulometry characterization of the current sediments of the study area. The grain size distribution analysis of sediments is important because they provide information on the sediments properties, the depositional conditions and environments, energy flowing as well as sediment transportation history (Folk and Ward, 1957). The results of these analyses are expressed as cumulative plot drawn on probability scale paper, percentiles of which can be derived to calculate the statistical parameters such as mean, sorting, skewness and kurtosis (Folk, 1966). Laser Diffraction Analysis is used for the grain size analysis, because of its advantages also taking into consideration the sediments nature, consisting mostly in sand. The data are generated and presented using Mastersizer 2000 software, which allow presenting a lot of data properties in one work paper.

2. Study Area

The Albanian coastline comprises about 454 km of rock and sandy beaches as Adriatic coastline and rocky escarpments as Ionian coastline (Durmishi et al, 2004). Mati Rives has a length of 115 km and the drainage basin of 2450km2, with maximum altitude is 746 m, which discharge in Adriatic coastline. In this river, Shkopet and Ulza hydro-powers are constructed. The main contributory is Fani River with the length of 94 km which discharges in Mati River. During Pliocene and Holocene, this area has been continually in elevation, creating a dense streams, which have developed a powerful dredging a carried activities in the medium flows, which made possible the creation of large accumulative cones on their estuaries. In general the Mati river basin is consider as mountain one (Kuliçi et al., 2012). The study area is Mati river delta which is situated in the north of Adriatic coastline, in the Per-Adriatic Depression, near to Rodoni Golf (Figure 1). In this delta are evidenced the ecosystems as: lagoon of Patoku, river mouth, Tale beach, littoral cordons, wetlands, abounded river channels. This delta is protected by the south current because of Rodoni Cape, for that the sediment input is leaded by the erosion of the uplifted hinterland. The river mouth has passed an evident dynamic, three river mouths were active until 1985; the main one was located in the middle. On 2008, the south estuary has been closed, created the conditions for the forming a new littoral. As it is shown in the sample location map in the Figure 2, was evidenced a sandy crest situated in the river mouth, which decrease the energy of river and favors the sea tide energy which affects the lower flow of river. The lower flow is composed by the Neogen – Quaternary depositions which have extension on the entire zone. These deposits are characterized from the combination of the argyles with coarse-grained sandstones massive in the lower part, limestone interbeds are present. The conglomerate sandstones are part of neogene depositions. Quaternary depositions have the larger extension on this zone, with a maximum of thickness until 200 meters near to Mati river delta (Kuliçi et al., 2012).

3. Methods and Materials

26 samples were taken in the deposits of Mati rivers delta from the coastline, in the shoreline Figure 1. The analysis of grain size distribution was performed using Laser Diffraction analysis (in the laboratories of KU Leuven, Belgium). Malvern instrument were used to perform the samples measurements, while the dataset management and processing were performed using Mastersizer 2000 software. The samples consist on sand, a few percentages of silt and clay. For that, the measurement procedure was carried out without pre-treatment of the samples. During the measurement, the ultrasonic device is activated, which help to split the particles, and lead to an accurate measurement.

3.1 Parameters calculation

The weight percentage and cumulative percentages were calculated for all Mati river delta samples. The classification of the grains size was based on the proposal of Went Worth 1922. Based on these results, were calculated the textural parameters as: mean (Folk, 1974), sorting, skewness, kurtosis (Folk & Ward 1957), also median (Trask 1930), and C (Φ99). In this paper the bivariate plots proposed by Folk (1966) were carried out for interpreting the results. The linear discriminant function (Y1, Y2, Y3, Y4), were calculated to decipher the deposition and environments conditions (Sahu, 1964). The geographic locations of the samples are presented in the Table 1.

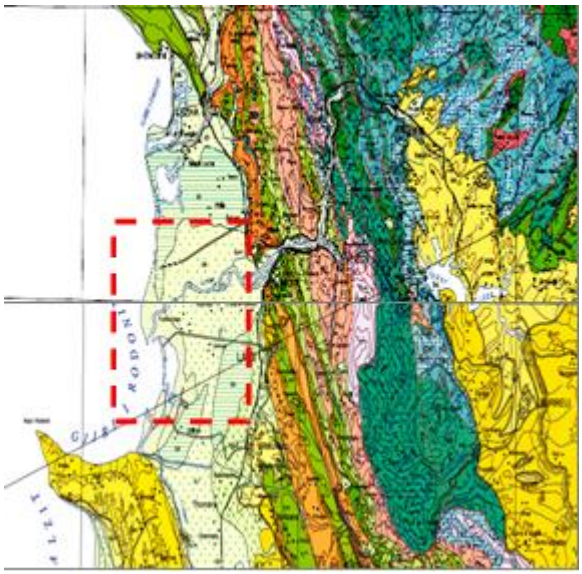


Figure 1: Geological Map of Mati River Delta (Sh.Gj.Sh, 2002). The study area is noted with red color line.

Figure 1: The map of samples locations

Table 1: The geographic coordinates of Mati river delta samples.

Sample	N	E
S. 8	41°37'23.9"	19°34'42.3"
S. 9	41°37'24.6"	19°34'41.9"
S. 10	41°37'26.6"	19°34'40.9"
S. 11	41°37'36.1"	19°34'33.3"
S. 12	41°41'56.3"	19°34'55.5"
S. 14	41°41'42.4"	19°34'52.6"
S. 15 (A,B)	41°41'25.7"	19°34'48.7"
S. 16 (A,B)	41°41'21.1"	19°34'47.5"
S. 17	41°41'14.2"	19°34'46.2"
S. 18 (A,B,C)	41°41'08.9"	19°34'44.9"
S. 19	41°41'08.5"	19°34'45.6"
S. 20	41°41'05.5"	19°34'43.1"
S. 21 (A,B,C)	41°40'50.0"	19°34'38.5"
S. 22	41°40'30.9"	19°34'29.5"
S. 23	41°39'41.0"	19°34'14.5"
S. 24 (A,B)	41°39'42.7"	19°34'14.9"
S. 25	41°39'48.1"	19°34'16.6"
S. 26	41°39'58.2"	19°34'18.1"
S. 27	41°40'16.4"	19°34'23.9"

4. Results and Discussion

4.1 Grain size distribution

Grain size distribution results are shown in the Table 2, based on the classification of the grain size proposed by the WentWorth, 1922. The sediment of Mati river delta consists on the medium sand (73%) and fine sand (27%) with a mixture of very fine and coarse sands. The clay fraction is in limited amounts up to 1.4%, with an average 0.7%. The silt fraction maximum is up to 2.20 and average 1.07%, while the coarse fraction consists up to 24%, with an average 7%. The grain sizes for beach sediments are important tool to distinguish the distance of the transport: the greater the distance the finer the size of grains. Here, the results indicate for medium to short distance of transport. The cumulative volume percentage curves show the unimodal in nature for all samples.

4.2 The statistical parameters

These curves were used to calculate the textural parameters as: mean (Mz); sorting (standard deviation σI); skewness (Ski) and kurtosis (KG), based on the proposal of Folk and Ward (1957). The results of the statistical parameters are given in the Table 2. Mean (Mz) - The mean grain size of the Mati river delta sediments points to the predominance of medium to fine sands. The mean values range from 1.4 Ø – 2.24 Ø, with an average of 1.9 Ø. These parameters are depended by the source supply, transporting and energy conditions of deposition environment (Folk, 1966). The majority values reveal for medium sands which indicates for the moderate energy conditions. While the variation of the phi values shows the different energy conditions. Related to the transport, the results indicate for medium to short distances. Sorting (Standard deviations σI) - It depends on the size range in the source rock, extent of weathering, distance of transportation and the energy variation of the depositing medium (Folk and Ward, 1957). The standard

deviation values range from 0.47 Ø – 0.66 Ø with average 0.57 Ø. Mati sediments are moderately well sorted, however one samples is well sorted S.8. Moderately well sorted indicate the influence of moderate to strong energy conditions in basin. This could be due to partial winnowing action, also addition or influx of previously sorted sediments in marine environment (Baiyegunhi et al., 2017). The dominance of the moderately well sorted sediments has been produced by sea tide energy, which has a big influence in this delta, also from the shore currents.

Table 2: The weight percentages of each fraction

No. Sample	<3.9 µm	<63 µm	63-125 µm	125-250 µm	250-500 µm	500 - 1 mm
S.8	0.4	0.5	5.6	61.6	31.9	0.0
S.9	0.4	0.5	3.1	50.8	41.7	3.5
S.10	0.6	1.0	2.3	45.0	49.1	2.0
S.11	0.4	0.6	2.1	41.2	50.2	5.5
S.14	0.4	0.6	2.3	40.5	50.7	5.5
S.15A	1.0	1.6	3.2	41.5	45.0	7.7
S.15B	1.4	2.1	4.7	50.4	37.7	3.7
S.16A	0.7	1.0	3.6	47.9	45.0	2.0
S.16B	0.9	1.0	4.9	59.9	33.1	0.2
S.17A	1.1	1.5	2.1	33.7	52.6	9.1
S.17B	1.2	2.2	2.5	37.2	49.5	7.4
S.17C	0.9	1.4	3.6	51.9	38.6	3.6
S.18/A	0.6	0.8	2.6	43.5	47.9	4.6
S.18B	0.8	1.0	3.1	50.9	42.6	1.7
S.18C	0.7	0.9	5.6	61.7	31.1	0.0
S.20	0.6	0.9	2.3	43.4	50.0	2.9
S.21/A	0.5	0.8	0.8	24.9	59.2	13.9
S.21/B	0.5	0.7	1.5	31.2	54.5	11.5
S.21/C	0.6	0.9	3.7	47.5	43.5	3.9
S.22	0.4	1.4	1.0	23.8	57.4	16.0
S.23	0.6	1.0	0.5	13.9	60.1	23.9
S.24A	0.9	1.8	0.9	24.9	58.8	12.7
S.24B	0.6	0.8	1.3	34.3	51.7	11.4
S.25	0.6	0.8	1.1	28.3	56.9	12.3
S.26	0.6	1.5	1.6	31.4	56.4	8.5
S.27	0.6	0.8	1.7	35.4	54.7	6.8

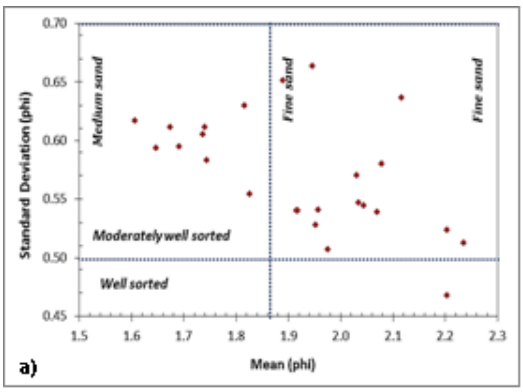
Skewness (Ski) –The values of skewness range form -0.05Ø to 0.082Ø, with an average of 0.008Ø. It is obvious that the sediments are symmetrical nature, indicating the absence of the extreme conditions. In these sediments it is clear the presence of the negative skewness due to the presence of the small coarse grain (Folk 1974), but it need to mentioned that the values are near to zero. Kurtosis (KG) –The kurtosis graph ranges from 0.99 Ø to 1.2Ø, with an average of 1.09Ø, distinguishing two groups, i.e. mesokurtic 65%; leptokurtic 35%. The mesokurtic to leptokurtic nature of sediments refers to the continuous additional of finer or coarser materials after the winnowing action and retention of their original characters during deposition (Avramidis, 2012). While three samples are shown as very leptokurtic distribution indicating for deposition in a fluvial or tidal environment, confirming that the sands are river derived.

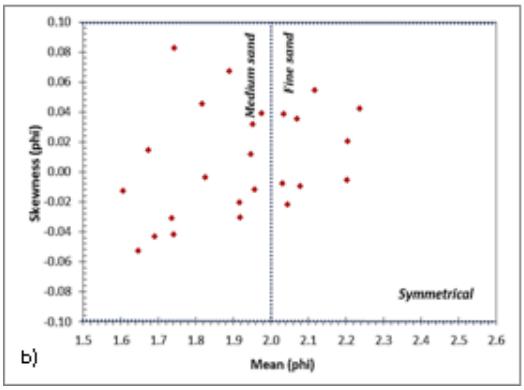
Freidman (1962) suggested that high or low values of kurtosis imply that part of the sediment achieved its sorting in high energy environment.

4.3 The bivariate plots of statistical parameters

Based on the study performed by Folk (1957) the bivariate plots are applied in the four size parameters (mean, sorting, skewness, kurtosis), plotting the parameters against each other as scatter diagrams *Figure 2*. The bivariate plots widely are used to obtain a better meaning of the textural parameters and to distinguish different deposition setting. The statistical parameters reflect differences in mechanisms of fluid flow of transportation and deposition of the sediments Table 3.

a) The mean size versus sorting bivariate plot – There is some covariance between these two parameters (Tucker, 2003) which can be explained by the fact that both parameters are hydraulically controlled; i.e. in each environment the well sorted sediments have the mean in the fine size range. The results shown that the samples of Mati river delta fall in the moderately well sorted, distributed in the medium and fine sands, but one sample fall in the well sorted and fine sand (S.8). The medium grain size and moderately well sorted indicates that the source region is not in large distance, also reveal for sediments reworked from waves actions.
b) The mean versus skewness bivariate plot – reveals that all samples are symmetrical for medium and fine sand. The medium deposits are more in number than fine deposits. The symmetrical skewed of the samples indicate that the mean and median values are almost equal.
c) The mean versus kurtosis bivariate plot – presents that 65% of the samples are mesokurtic followed by leptokurtic 35% for both fine and medium sand. In the fine fraction the most of the samples are mesokurtic nature only two samples are leptokurtic, while in the medium sands both types are evidenced.





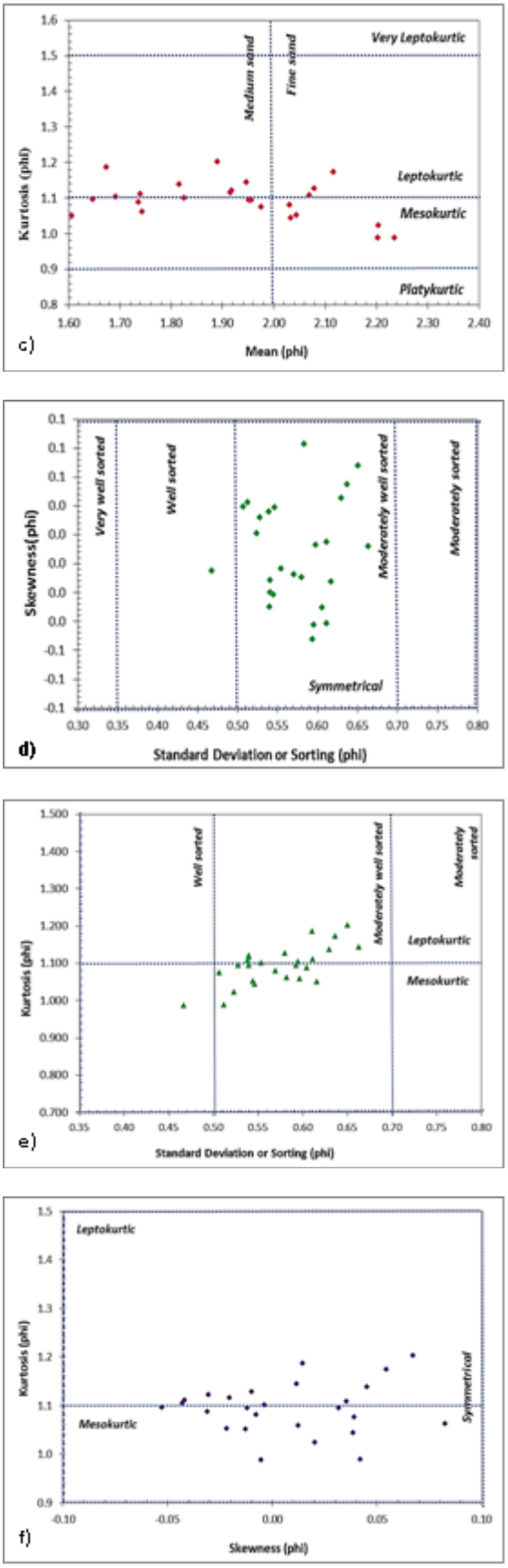


Figure 2: Bivariate plots: a) Mean vs Sorting; b) Mean vs Skewness; c) Mean vs Kurtosis; d) Sorting vs Skewness; e) Sorting vs Kurtosis; f) Skewness vs Kurtosis

d) The sorting versus skewness bivariate plot - reveals that the sediments are symmetrical and moderately well sorted, only a sample show symmetrical skewed and well sorted.

e) The sorting versus kurtosis bivariate plot – reveals that samples are dominantly moderately well sorted and display a mesokurtic to leptokurtic distribution. Only the S.8 show well sorted with mesokurtic distribution. It is obvious that a positive correlation between these parameters, kurtosis value increases with increase in sorting of sediments.

f) The skewness versus kurtosis bivariate plot - is used to distinguish the environment of deposition. The samples of Mati river delta are mostly mesokurtic distribution and display symmetrical to leptokurtic and symmetrical skewed. The plot show that as the kurtosis values increases, the sediments are getting positive skewed.

Table 3: The statistical parameters of Mati river delta sediments. *(S.D-standard deviation, Ski-skewness, KG-kurtosis, WS- well sorted, MWS-moderately well sorted, S-symmetrical, MK-Mesokurtosis, LK-Leptokurtosis).*

Sample	Mean (Ø)	Med (µm)	C (µm)	S.D (Ø)	Ski (Ø)	KG	S.D	Ski	KG
S.8	2.20	215	416	0.47	-0.01	0.99	WS	S	Mk
S.9	2.04	242	630	0.54	-0.02	1.05	MWS	S	MK
S.10	1.97	255	528	0.51	0.04	1.08	MWS	S	MK
S.11	1.92	263	698	0.54	-0.03	1.12	MWS	S	LK
S.14	1.92	264	698	0.54	-0.02	1.12	MWS	S	LK
S.15A	1.95	260	753	0.66	0.01	1.14	MWS	S	LK
S.15B	2.12	232	631	0.64	0.05	1.17	MWS	S	LK
S.16A	2.03	245	535	0.55	0.04	1.04	MWS	S	MK
S.16B	2.20	217	463	0.52	0.02	1.02	MWS	S	MK
S.17A	1.82	285	690	0.63	0.05	1.14	MWS	S	LK
S.17B	1.89	271	681	0.65	0.07	1.20	MWS	S	LK
S.17C	2.08	235	612	0.58	-0.01	1.13	MWS	S	LK
S.18/A	1.96	256	664	0.54	-0.01	1.10	MWS	S	MK
S.18B	2.07	240	518	0.54	0.04	1.11	MWS	S	MK
S.18C	2.24	214	425	0.51	0.04	0.99	MWS	S	MK
S.20	1.95	259	550	0.53	0.03	1.09	MWS	S	MK
S.21/A	1.65	316	814	0.59	-0.05	1.10	MWS	S	MK
S.21/B	1.74	296	793	0.61	-0.04	1.11	MWS	S	LK
S.21/C	2.03	244	647	0.57	-0.01	1.08	MWS	S	MK
S.22	1.61	326	814	0.62	-0.01	1.05	MWS	S	MK
S.23	1.40	375	835	0.60	0.01	1.06	MWS	S	MK
S.24A	1.67	313	805	0.61	0.01	1.19	MWS	S	LK
S.24B	1.74	297	810	0.61	-0.03	1.09	MWS	S	MK
S.25	1.69	306	793	0.60	-0.04	1.10	MWS	S	MK
S.26	1.74	302	630	0.58	0.08	1.06	MWS	S	MK
S.27	1.83	281	664	0.55	0.00	1.10	MWS	S	MK

4.4 The Linear Discriminate Functions

For the interpretation of the processes and depositional environment of sediments, the LDF (linear discriminant function), proposed by Sahu (1964), were calculated.

The equations of LDF are mentioned below (Maity et al., 2016; Rashedi et al., 2016):

$Y1 = -3.5688M + 3.7016SD^2 - 2.0766SK + 3.1135KG$

(If Y1 is < -2.7411 the environment is classified as "Aeolian" and if Y1 is > -2.7411 the environment is considered as "Beach");

$Y2 = 15.6534M + 65.7091\ SD^2 + 18.1071SK + 18.5043KG$

(If Y2 is > 65.365 the environment is classified as "shallow agitated water" and if Y2 is < 65.365, the environment is considered as "beach/backshore");

$Y3 = 0.2852M - 8.7604\ SD^2 - 4.8932SK + 0.0482KG$
(If Y3 is < −7.419, the environment is classified as "fluvial/deltaic" and if Y3 is > −7.419, the environment is considered as "Shallow marine").

$Y4 = 4.5129M - 1.2837\ SD^2 + 3.5904SK + 4.1038KG$
(If Y4 is < 9.81, it indicates turbidity current deposition and if Y4 is > 9.81, it indicates deltaic deposition).
- where M = Mean grain size; SD= standard deviation; SK = skewness; KG = kurtosis.

Refer to the values of Y1; the samples of the Mati river delta are plotted in the Beach (73%) and Aeolian (27%) domain. For the function Y2, the samples of this delta are classified as shallow agitated water (96.2%) and as beach (backshore) (3.8%). Related to the Y3 value, all the samples fall in shallow marine, same as Y4 value reveal that all the samples fall in fluvial field (Table 4).

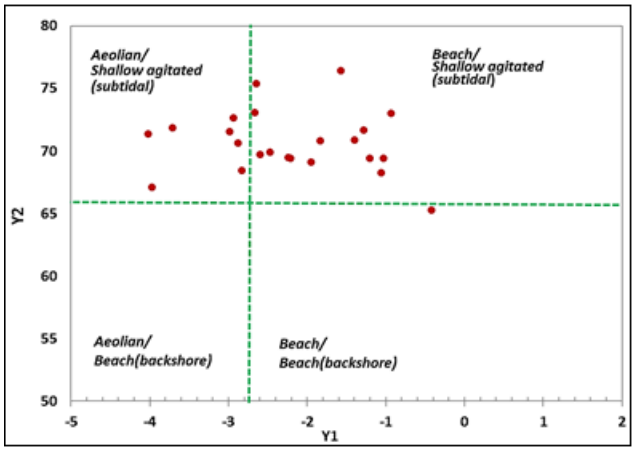


Figure 3: LDF on Y1 vs Y2

Plotting Y1 versus Y2 (Figure 4) shows that Mati samples fall in three fields, but mostly in the beach/shallow agitated water domain followed by Aeolian/shallow agitated water settings. Only one samples fall in beach/beach backshore. The plot of Y3 against Y2 (Figure 5) indicates that the Mati samples plot in the shallow agitated water/shallow marine domain, but only sample fall in the beach/shallow marine. While the plot of Y4 against Y3 (Figure 6) reveals that the samples correspond to shallow marine and fluvial deposits. Only one sample has different characteristic from the majority, situated in the abandoned channel in the north of the main river mouth.

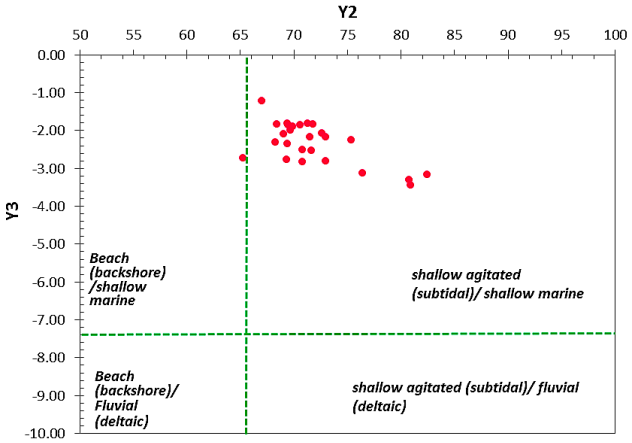


Figure 4: LDF on Y2 vs Y3

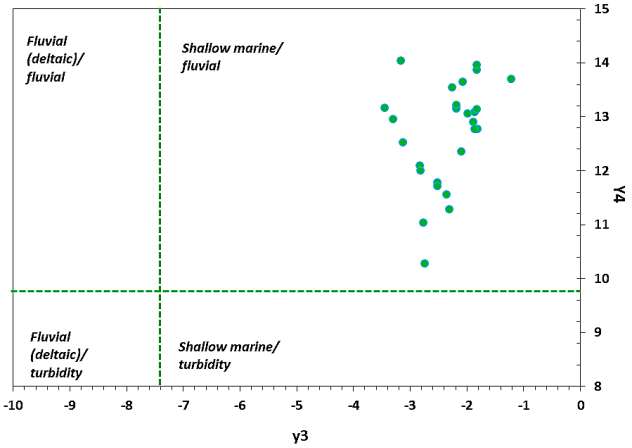


Figure 5: LDF on Y3 vs Y4.

5. Conclusions

The grain size analyses for 26 samples of Mati river delta in Albania were analyzed using Laser Diffraction analysis. The measurements are performed using a Malvern Instrument while the data are generated using Malvern 2000 software. The main conclusions of this study are:

- The grain size distribution indicate dominance medium sand to fine sand, showing unimodal grain size distributions, which is indicative for moderate energy environment.
- The statistical parameters of grain size reveal that samples are mostly moderately well sorted, near symmetrical skewed, possessing mostly a mesokurtic to leptokurtic distribution.
- Bivariate plots are performed with different parameters reveal for the presence of moderately energy conditions, the source region is not in large distance, also reveal for sediments reworked from tide and waves actions.
- The linear discriminant function analysis indicates that sediments were deposited mostly under shallow marine environmental conditions, reworked by beach and Aeolian processes and fluvial deposits.

Table 4: The values of LDF and remarks on the deposition environment

Sample	Y1	Y2	Y3	Y4	Y1	Y2	Y3	Y4
S.8	-3.97	67.04	-1.21	13.70	A	B(b)	SH.M	F
S.9	-2.87	70.57	-1.86	13.08	A	B(b)	SH.M	F
S.10	-2.83	68.41	-1.83	13.14	A	B(b)	SH.M	F
S.11	-2.21	69.39	-1.81	12.77	B	B(b)	SH.M	F
S.14	-2.24	69.46	-1.86	12.78	B	B(b)	SH.M	F
S.15A	-1.78	80.75	-3.30	12.95	B	B(b)	SH.M	F
S.15B	-2.51	82.49	-3.16	14.04	B	B(b)	SH.M	F
S.16A	-2.98	71.50	-2.18	13.22	A	B(b)	SH.M	F
S.16B	-3.71	71.81	-1.82	13.87	A	B(b)	SH.M	F
S.17A	-1.56	76.39	-3.13	12.52	B	B(b)	SH.M	F
S.17B	-1.57	80.90	-3.44	13.16	B	B(b)	SH.M	F
S.17C	-2.64	75.36	-2.26	13.54	B	B(b)	SH.M	F
S.18/A	-2.47	69.88	-1.89	12.91	B	B(b)	SH.M	F
S.18B	-2.93	72.63	-2.07	13.64	A	B(b)	SH.M	F
S.18C	-4.01	71.31	-1.82	13.96	A	B(b)	SH.M	F
S.20	-2.59	69.71	-1.99	13.06	B	B(b)	SH.M	F
S.21/A	-1.05	68.24	-2.30	11.29	B	B(b)	SH.M	F
S.21/B	-1.28	71.61	-2.52	11.78	B	B(b)	SH.M	F
S.21/C	-2.66	73.00	-2.18	13.15	B	B(b)	SH.M	F
S.22	-1.03	69.36	-2.76	11.03	B	B(b)	SH.M	F
S.23	-0.42	65.27	-2.74	10.27	B	SH.A	SH.M	F
S.24A	-0.93	72.98	-2.81	12.00	B	B(b)	SH.M	F
S.24B	-1.39	70.84	-2.51	11.72	B	B(b)	SH.M	F
S.25	-1.20	69.39	-2.36	11.55	B	B(b)	SH.M	F
S.26	-1.83	70.77	-2.83	12.09	B	B(b)	SH.M	F
S.27	-1.94	69.05	-2.10	12.35	B	B(b)	SH.M	F

(A-Aeolian, B-beach, B(b)-Beach(backshore), Sh.A-shallow agitated water, Sh.M-shallow marine, F-Fluvial).

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