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Determining the variation of soil properties in the Batumi Delta

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Abstract. The aim of this study was to determine certain basic properties of soils in the Batumi delta, to determine the relationships of studied properties, and to identify differences with regards to these properties between different sampling sites in the delta that were selected based on the delta morphology. In this context, a total of 125 soil samples were collected from five different sampling sites, and the clay, silt and sand content of the samples were determined along with their mean weight diameter (MWD) values, aggregate stability (AS) values, amount of water retained under -33 kPa (FC) and -1500 kPa (WP) pressure and organic matter (OM) content. Correlation analysis indicated that clay content and OM were positively correlated with MWD, and OM was positively correlated with AS. However, the sand content was found to be negatively correlated with MWD. In addition, clay, silt and OM content were positive correlated with FC and WP. Variance analysis results determined statistically significant differences between the sampling sites with respect to all of the evaluated properties. The active delta section of the study area was characterized by high sand content, while the lower delta plain was characterized by high OM and AS values, and the upper delta plain was characterized by high WMD values, high FC and WP moisture content levels and high clay and silt content. In conclusion, it was demonstrated that the examined properties were significantly affected by the different morphological positions and usages of these different areas. These results may help with the management of agricultural lands in the Batumi delta, which has never been studied before.

1 Introduction

Soil is a key part of the Earth System as control the hydrological, erosional, biochemical and biological cycles (Brevik et al., 2015; Decock et al., 2015; Smith et al., 2015). Soil contributes to basic human needs like food, clean water, and clean air, and are a major carrier for biodiversity (Keesstra et al., 2016). A consequence of soils forming at the intersection of the atmosphere, biosphere, and lithosphere (Brevik et al., 2015). Thus, soils covered the Earth vary even in the small scales in terms of their properties.

Deltas, which are one of the best examples of alluvial soils, are geomorphological structures that result from the depositing and accumulation of alluvial material at estuaries (Erinç, 2001). Owing to the wetlands and high biodiversity they harbor and to their high potential for agricultural production, deltas are areas of great ecological and agricultural significance (Imentai et al., 2015; Khai and Yabe, 2015; Gillison et al., 2016). Depending on the time of accumulation of the alluvial materials, the delta morphology consists of three distinct areas, which, starting from the coast, are the active delta area, the lower deltaic plain and the upper deltaic plain (Erinç, 2001). These parts of deltas show differences in terms of soil properties (Søvik and Aagaard, 2003; Unverricht et al., 2013).

In deltas, the fact different that sections have formed at different times also leads to differences in the way these areas are utilized. The active delta section, which is youngest section of deltas, generally lack any notable agricultural production activity, while the upper deltaic plains, which are older in terms of their time of formation, are areas of extensive agricultural activity. The different agricultural use of different delta areas also results in the differences between their soil properties. Numerous researchers have reported that differences in the utilization of delta areas contribute to considerable differences in soil properties (Huang et al., 2012; Deng et al., 2016; Hernández et al., 2016; Madhavan et al., 2016). Conducting agricultural production in delta soils first requires reclamation activities (Krishnamoorthy et al., 2014). It is known that reclamation activities such as plowing, irrigation and fertilization causes changes in the physical (Jiao et al., 2014; Li et al., 2014) and chemical properties (Cui et al., 2012; Han et al., 2014; Jiao et al., 2014) of the soil.

The Batumi delta, which is fed with water and materials carried by the Çoruh and Adjaristkali rivers, is one of Georgia's most important agricultural production areas. The subtropical climate of the region has promoted a diversity of agricultural production activities. Although the Batumi delta is a very important area of agricultural production, there are currently no studies that have investigated the properties of its soils. The aim of this study was (i) to determine the general properties of soils in the Batumi delta, (ii) to determine the relationships of studied properties and (iii) to compare these properties between different delta areas that are considered to be morphologically different.

2 Material and Methods

2.1 Study area

The presented study was conducted in the Batumi Delta, located in the south-west part of Georgia (Figure 1). The delta covers an area approximately of 3900ha. The delta is flat with an elevation ranging from 2 to 50m above the sea level (Figure 1). The main form of land use in the delta is agriculture, which is especially dominant in the lower deltaic plain and upper deltaic plain, while the active deltaic plain is covered by pastures. The most commonly grown crops are vegetable and tangerine. The investigated area is characterized by a humid subtropical climate, with an annual average temperature of 14.4 ^{o}C and annual precipitation of 2718mm.

2.2 Sampling pattern and analyses

The Batumi delta was divided into five different sites based on morphological differences. The first site consisted of the active delta area (L1), while the second and third sites comprised the lower deltaic plain (L2 and L3), and the fourth and fifth sites comprised the upper deltaic plain (L4 and L5) (Figure 2). Information on these sites are provided in Table 1. In each one of these sites, soils samples were collected at 25 different points from the surface layer (0 – 20cm).

Soil samples were air-dried and passed through a 2mm sieve. Particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986), while aggregate stability for 0.25-0.50mm, 0.50-1.00mm and 1.00–2.00mm sizes aggregate was determined with the Yoder wet-sieving method (Kemper and Rosenau, 1986). Soil organic matter content was determined by the Walkley-Black method (Schnitzer, 1982). Mean weight diameter was calculated using following Eq. 1(Van Bavel, 1950):

$$MWD = \sum_{i=1}^{n} x_i y_i \quad (1)$$

where y_i is the proportion of each size class by weight with respect to the total sample and x_i is the mean diameter of the size classes (mm).

Analysis was performed in three replicated for each soil sample. Descriptive statistics, including averages, standard deviation, minimum and maximum values, and the coefficient of variation were determined for all the studied soil properties. The correlation analysis was performed to assess the relationships between variables, the analysis of variance was applied in determining the differences between the sampling sites. JMP 5.0 package software was used in conducting statistical analyses (JMP, 2007).

3 Results

3.1 Descriptive statistics

Table 2 shows the descriptive statistic results regarding the soil properties examined in study. The clay content of the soils within the study area varied between 1.47% and 24.21%, with a mean level of 8.91%; in this respect, the clay content constituted the lowest fraction in the soils. The silt content of the soils varied between 4.90% and 53.41%, with a mean level of 29.13%. The sand content of the soils varied between 36.04% and 92.11%, with a mean level of 92.11%. Sand content thus constituted highest fraction in the soils within the study area. The mean weight diameter (MWD) of the aggregates within the study area varied between 0.26mm and 1.02mm, while the average MWD was calculated as 0.64mm.

The aggregate stability (AS) of the studied soils were separately calculated for each class of aggregate size. For the largest aggregate size class (1.00-2.00mm, AS_1), aggregate stability values varied between 40.08% and 95.40%, while the mean AS_1 level was 82.06%, which indicated "very good" aggregate stability (Dilkova et al., 2002). For the second largest aggregate size class (0.50-1.00mm, AS_2), aggregate stability values varied between 32.88% and 95.68%, while the mean AS_2 level was 82.06%, which indicated "very good" aggregate stability. For the smallest aggregate size class (0.25-0.50mm, AS_3), aggregate stability values varied between 58.56% and 95.31%, while the mean AS_3 level was 86.01%, which again indicated "very good" aggregate stability.

The moisture content retained by the soils at -33kPa (i.e. the soil field capacity, FC) varied between 5.29% to 57.10% of the soil mass, with a mean level of 29.84%. On the other hand, the moisture content retained by the soils at -1500kPa (i.e. the soil wilting point, WP) varied between 2. 92% to 49.32% of the soil mass, with a mean level of 22.84%. The values determined for both moisture constants were higher than the values normally observed for the predominant soil texture class found in the study area (Karaman et al., 2007).

The organic matter content of the soils varied between 0.37% and 5.63%, with a mean level of 2.53%. It was determined that this level of organic matter content is relatively high for soils belonging to the sandy loam texture class (Marchetti et al., 2012).

Among the different properties that were examined, the lowest variation coefficient was calculated for the AS_3 values (9.45%), while the highest variation coefficient was calculated for the clay content (54.70%). In other words, the most homogenous property in the study areas was AS_3, while the most heterogeneous one was clay content. With respect to the particle size distribution, clay content was the most heterogeneous soil property, and sand content was the most homogeneous soil property. With respect to aggregate stability, AS_1 was the most heterogeneous soil property, and AS_3 was the most homogeneous soil property. With respect to moisture constants, FC was found to be more homogenous property.

3.2 Correlation analysis results

The results for the correlation analysis between the examined soil characteristics are shown in Table 3. Based on the analysis results, positive correlation was identified between MWD and the clay and OM of soils, while negative correlation was identified between MWD and sand content. As well positive correlation was identified between OM and AS. It was also observed that the effect of OM on AS values decreased in parallel to the decrease in aggregate size.

Correlation analysis results evaluating the relationship between the soil water constants and the soil characteristics in question indicated statistically significant relationships between all the soil characteristics on one hand, and the FC and WP on the other. Evaluation of the correlation coefficients showed that the OM had a greater effect of FC, while the clay, silt and sand contents had a greater effect of WP.

3.3 Variance analysis results

The difference between the sampling sites with respect to their clay contents was found to be statistically significant ($p<0.01$). The lowest clay content was observed in the L1 (5.07%), which is also the youngest deposit area. The L1 was followed, in increasing order of clay content, by the L2 (6.58%), L3 (9.37%) and L4 (10.27%), while the L5, considered to be the oldest deposit area, had the highest clay content value (13.32%) (Table 4). The difference between the sampling sites with respect to their silt contents was also found to be statistically significant ($p<0.01$). The high silt content was observed in the L5 (34.91%), which was followed, in decreasing order of silt content, by the L3 (31.18%), L1 (27%), L4 (26.79%) and L2 (25. 73%) (Table 4). The sand content was found to vary significantly depending on the sampling site ($p<0.01$). An evaluation of the multiple comparison tests reveals that the high sand content was found in the L1 (67.91%) and L2 (67.67%), followed by the L4 (62.40%), L3 (57.98%) and L5 (51.13%) (Table 4).

The MWD of the soils was also found to vary significantly depending on the deposit area ($p<0.01$). Study results indicated that the highest MWD values were observed in the L5 (0.82mm), followed by the L4 (0.77mm), L3 (0.65mm) and L2 (0.56mm), and with L1 having the lowest mean weight diameter (0.35mm) (Table 4).

Aggregate stability values for the different aggregate classes (AS_1, AS_2, AS_3) were found to vary significantly depending on the deposit area ($p<0.01$). AS_1 values were higher in L2 (90.95%) and L3 (89.3%) where cultivation activities are minimal, while lower AS_1 values were observed in areas of agricultural production, which are characterized by higher levels of plowing and cultivation activities (L4 and L5, with AS_1 values of 86.67% and 83.60%, respectively). Aggregate stability values were the lowest in the L1 sampling site (58.51%), which is a young deposit area (Table 4).

The level of variation between FC of the sampling sites was found to be statistically significant ($p<0.01$). Based on the study results, the highest FC was observed in the L4 (35.59%), which was followed by the L5 (35.4%), L3 (32.98%) and L2 (27.74%), with the lowest FC being observed in the L1 (17.47%) (Table 4). The WP of the soils in different sampling sites also showed significant variation ($p<0.01$). According to the study results, the highest WP was observed in the L5 (28.62%), which was followed by the L4 (27.98%), L3 (25.3%) and L2 (19.2%), with the lowest WP being observed in the L1 (13.06%).

Variance analysis results showed that the variation in the OM of the sampling sites was statistically significant ($p<0.01$). Between the different sampling sites, the highest OM was observed in L2 (3.31%), which was followed by L4 (3.1%), L5 (2.64%) and L3 (2.59%). The lowest OM content was calculated for the L1 (0.98%) (Table 4).

4 Discussion

Assessments performed with the aim of determining soil aggregation have shown that soil fractions and organic matter content have varying effects on the mean weight diameter (MWD) and aggregate stability (AS). It was determined that clay, sand and organic matter content (OM) have a significant effect on the MWD of soils, while only OM have a significant effect on AS. It is known that aggregation occurs as a result of the reorganization, flocculation and binding soil particles (Duiker et al., 2003), and that this process is also mediated by the soil organic carbon, biota, ionic bridges, clay and carbonates (Bronick and Lal, 2005). According to Tisdall and Oades (1982), aggregates form sequentially based on a certain hierarchy, with different binding mechanisms being involved at every stage. In this hierarchy; clay, multivalent ions and organic materials congregate to form micro-aggregates (<250 μm), and these constituents then congregate with other micro-aggregates to form macro-aggregates (>250 μm) (Tisdall, 1996). An increase in soil organic matter content also means an increase in the amount of organic molecules that have a binding effect. The increase in the ratio of binding materials between particles results in a more solid aggregate structure. Based on these general observations, it is expected that an increase in clay content will be associated with an increase in MWD values, and OM will be associated with an increase in AS values. Similarly to our study results, other researchers have also reported a positive correlations between the MWD and the clay (Chrenková et al., 2014), and MWD and organic matter content (Campo et al., 2014; Cheng et al., 2015; Zhang et al., 2016). In addition, certain researchers have also reported that the increase in OM leads to an increase in AS values (Aksakal et al., 2015; Obia et al., 2016; Simansky et al., 2016; Wang et al., 2016).

The most important factor that affects water retention in soil is the pore diameter and geometry. For this reason, the soil texture, structure and organic matter content factors that affect pore size distribution in the soil are also known to indirectly influence the soil retention (Hillel, 1971; Karaman et al., 2007). It is known that two main forces affect water retention in soil: One of these is the adherence of solid soil particles to water molecules, or adhesion, while the other is the adherence of water molecules to one another, or cohesion. Adhesion results from the adsorption of water by organic and inorganic soil colloids (Ergene, 2012). An increase in the clay and organic matter content also leads to an increase in water retention (Hillel, 1971; Kirkham, 2004). Our study findings are in agreement with these general observations, with the increase in clay and OM resulting in an increase in the amount of water retention at pressures of -33kPa (FC) and -1500kPa (WP). In parallel with our study results, other researchers have also reported that an increase in clay content (Ding et al., 2016; Nguyen et al., 2015; Obia et al., 2016) and organic matter content (Guo et al., 2016; Obia et al., 2016; Yang et al., 2014) is associated with an increase in field capacity and wilting point water content values.

It was observed that the clay content of the soil gradually increased moving from the active delta area towards the upper deltaic plain, while the sand content gradually decreased in the same direction. It is believed that there are two main underlying reasons for this variation: The first is the usage of the relevant areas, while the second is the morphological position of the sampling sites. Over the course of a delta's morphological development, new material is deposited in the active delta area, while the more inland areas will be converted into areas of agricultural production. It is known that the physical properties of coastal soils – such as soil particle size, aggregate, soil moisture – will eventually change as a result of reclamation actions such as plowing, irrigation and fertilization (Li et al., 2014). Similarly to our study results, other researchers also report that reclamation activities lead to a decrease in particle size (Li et al., 2012; Sun et al., 2011). It is believed that seasonal variations in the flow regime of rivers that feed the delta especially causes clay sized particles in the active delta section to be carried away. Studies on alluvial plains also report that areas closer to the riverbed have soils with higher sand content, while the soil sand content gradually decreases at increasing distances from the riverbed (Scott, 2000; Turgut and Öztaş, 2012). It is also believed that areas of deltas closer to the sea are more exposed to wave movement, which cause clay particles to be carried away from the delta by waves. In parallel with our study results, Yu et al. (2015) determined in their study on delta soils that the sand content was higher in soils closer to the sea, and gradually decreased at increasing distances from the sea.

A prerequisite for aggregation is that the clay must be flocculated (Hillel, 2003); and in the field, adjacent aggregates often tend to adhere to one another, though certainly not as strongly as do the particles within each aggregate. For this reason, it was expected that the lowest clay content would be observed in soils from the L1, and that the MWD values for these soils would be the lowest. It was also expected that an increase in soil clay content would be associated with a higher MWD value. Similarly to our study results, other researchers have also reported that an increase in clay content for sandy soils led to an increase in MWD values (Chrenková et al., 2014; Wang et al., 2016).

Aggregate stability is defined as the resistance exhibited by aggregate against mechanical shearing forces and the dispersing effect of water (Scott, 2000). Factors which affect the formation of stable aggregates within the soil include the wetting and drying cycle, the freezing and thawing cycle, and the presence of clay, Fe/Al oxides and organic matter in the soil (Abid and Lal, 2008; Karaman et al., 2007). Aggregate stability values tend to increase in parallel with increasing organic matter content (Bravo-Garza et al., 2010; Joseph Oyedele et al., 1999; Plante and McGill, 2002a; Plante and McGillb, 2002b; Soinne et al., 2016; Tisdall and Oades, 1982). Soil cultivation activities, on the other hand, are known to reduce aggregate stability values (Jury and Horton, 2004; Plante and McGill, 2002a; Scott, 2000). The results of our study were generally in agreement with the literature, in that higher OM was found to be associated with higher AS, while areas subject to cultivation activities generally had lower AS. Other researchers similarly report a relationship between higher organic matter content and higher aggregate stability (Bravo-Garza et al., 2010; Soinne et al., 2016; Turgut et al., 2015), and the relationship between higher sand content and lower aggregate stability (Chrenková et al., 2014). Various researchers also report that soil cultivation has the effect of reducing aggregate stability (Plante and McGill, 2002b; Shu et al., 2015; Soinne et al., 2016).

The soil texture and structure affects the pore size and geometry of soils, which in turn affects their moisture constants. Owing to their high water retention capacity, and their ability to improve the structural properties of soils; organic matter also have a positive effect on the soil moisture values (Karaman et al., 2007). For this reason, areas with high mean weight diameter, clay content and organic matter content values are also expected to have high field capacity and wilting point moisture contents. In parallel with out study's findings, other researchers have also reported higher field capacity and wilting point moisture content with increasing organic matter (Bauer and Black, 1992; Hudson, 1994; Peake et al., 2014; Nguyen et al., 2015) and clay content (Hudson, 1994; Rawls et al., 2003).

It is known that vegetation has a direct effect on the soil organic matter content. Soil organic content is constituted of plant and animal remains (Baldock and Nelson, 2000; Karaman et al., 2007), and is directly associated with the plant biomass (Sollins et al. 1996, Jaiarree et al. 2011, Novara et al. 2013). In the present study, OM was the lowest in the L1, which is believed to be associated with the sparsely distributed vegetation in this area. Vegetation in the L2 consisted predominantly of bushes, which led to a higher OM in the area. In the other areas (L3, L4 and L5), it was observed that due to agricultural activities that accelerate the mineralization of organic matter, OM was lower compared to the L2. Similarly to our study results, other researchers have also reported that the soil organic matter content of natural pastures and prairies is higher than that of areas used for cultivation (Cates et al., 2016; Gajić, 2013; Kodešová et al., 2011).

5 Conclusion

This study conducted in the Batumi delta demonstrated that the variation in soil properties can be described based on differences in land use and the morphological location of the sampling sites. For this reason, the variation observed in soil properties according to different land use and morphological location can be used as a reference for evaluating delta soils. The results of the present study provides scientific data for land use management in Batumi delta, which has never been studied before.

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Table 1: Morphological position, land use type and location of sampling sites

Sampling site	Morphological position	Land use type	Gradient	Elevation (m)	Coordinate (UTM, 37T)

					North	East
L1	Active delta	Pasture	Flat	3	4608002	715853
L2	Lower deltaic plain	Pasture	Flat	8	4607475	715986
L3	Lower deltaic plain	Orchard (tangerine) and pasture	Flat	8	4611062	717270
L4	Upper deltaic plain	Orchard (tangerine)	Flat	8	4606381	715325
L5	Upper deltaic plain	Orchard (tangerine) and vegetable fields	Flat	18	4609295	719522

Table 2: Summary statistics of soil properties

Variable	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation (%)
Clay	1.47	24.21	8.91	4.87	54.70
Silt	4.90	53.41	29.13	9.07	31.14
Sand	36.04	92.11	61.42	12.22	19.90
MWD	0.26	1.02	0.64	0.19	30.13
AS_1	40.08	95.40	82.06	12.94	15.77
AS_2	32.88	95.68	82.69	12.38	14.97
AS_3	58.56	95.31	86.01	8.13	9.45
FC	5.29	57.10	29.84	9.08	30.44
WP	2.92	49.32	22.84	8.43	36.90
OM	0.37	5.63	2.53	1.25	49.49

MWD, mean weight diameter; OM, organic matter content; AS_1, aggregate stability of 1.00-2.00mm aggregate size; AS_2, aggregate stability of 0.50-1.00mm aggregate size; AS_3, aggregate stability of 0.25-0.50mm aggregate size; FC, water retention in -33kPa; WP, water retention in -1500kPa.

Table 3: Correlation matrix of investigated soil properties

Variables	Clay	Silt	Sand	OM	MWD	AS_1	AS_2	AS_3	FC
Silt	**0.414**								
Sand	**-0.699**	**-0.900**							
OM	0.056	-0.005	-0.034						
MWD	**0.651**	0.152	**-0.437**	**0.458**					
AS_1	0.165	0.053	-0.106	**0.620**	**0.460**				
AS_2	0.097	-0.062	0.015	**0.550**	**0.402**	**0.871**			
AS_3	-0.034	-0.100	0.121	**0.485**	**0.230**	**0.830**	**0.845**		
FC	**0.517**	**0.409**	**-0.556**	**0.604**	**0.757**	**0.548**	**0.456**	**0.298**	
WP	**0.535**	**0.460**	**-0.607**	**0.540**	**0.746**	**0.437**	**0.326**	0.169	**0.963**

Values in bold are different from 0 with a significance level alpha=0.01

MWD, mean weight diameter; OM, organic matter content; AS_1, aggregate stability of 1.00-2.00mm aggregate size; AS_2, aggregate stability of 0.50-1.00mm aggregate size; AS_3, aggregate stability of 0.25-0.50mm aggregate size; FC, water retention in -33kPa; WP, water retention in -1500kPa.

Table 4: Summary of ANOVA for soil properties

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Properties	L1	L2	L3	L4	L5
Clay	$5.07^{D}\pm2.80$	$6.58^{CD}\pm3.09$	$9.37^{BC}\pm4.14$	$10.27^{AB}\pm5.03$	$13.32^{A}\pm4.27$
Silt	$27.00^{B}\pm14.93$	$25.73^{B}\pm4.88$	$31.18^{AB}\pm6.63$	$26.79^{B}\pm5.90$	$34.91^{A}\pm6.12$
Sand	$67.91^{A}\pm17.29$	$67.67^{A}\pm6.67$	$57.98^{BC}\pm8.32$	$62.40^{AB}\pm10.18$	$51.13^{C}\pm6.84$
MWD	$0.35^{D}\pm0.06$	$0.56^{C}\pm0.07$	$0.65^{B}\pm0.13$	$0.77^{A}\pm0.12$	$0.82^{A}\pm0.08$
AS_1	$58.51^{C}\pm9.01$	$90.95^{A}\pm3.29$	$89.13^{A}\pm4.53$	$86.67^{AB}\pm4.65$	$83.60^{B}\pm5.07$
AS_2	$63.81^{C}\pm13.80$	$89.91^{A}\pm4.18$	$88.35^{AB}\pm6.62$	$88.52^{AB}\pm4.31$	$83.34^{B}\pm5.01$
AS_3	$75.24^{C}\pm9.55$	$91.56^{A}\pm2.73$	$89.23^{A}\pm5.66$	$84.23^{A}\pm3.43$	$84.76^{B}\pm5.10$
OM	$0.98^{B}\pm0.39$	$3.31^{A}\pm1.02$	$2.59^{A}\pm0.99$	$3.10^{A}\pm1.25$	$2.64^{A}\pm0.89$
FC	$17.47^{C}\pm7.25$	$27.74^{B}\pm5.74$	$32.98^{A}\pm4.92$	$35.59^{A}\pm7.55$	$35.40^{A}\pm4.30$
WP	$13.06^{C}\pm7.94$	$19.20^{B}\pm4.26$	$25.30^{A}\pm5.15$	$27.98^{A}\pm7.30$	$28.62^{A}\pm4.86$

L1, L2, L3, L4 and L5 indicate sampling sites. Means with capital and small letters indicate significant differences; 0.01 and 0.05, respectively. MWD, mean weight diameter; OM, organic matter content; AS_1, aggregate stability of 1.00-2.00mm aggregate size; AS_2, aggregate stability of 0.50-1.00mm aggregate size; AS_3, aggregate stability of 0.25-0.50mm aggregate size; FC, water retention in -33kPa; WP, water retention in -1500kPa.

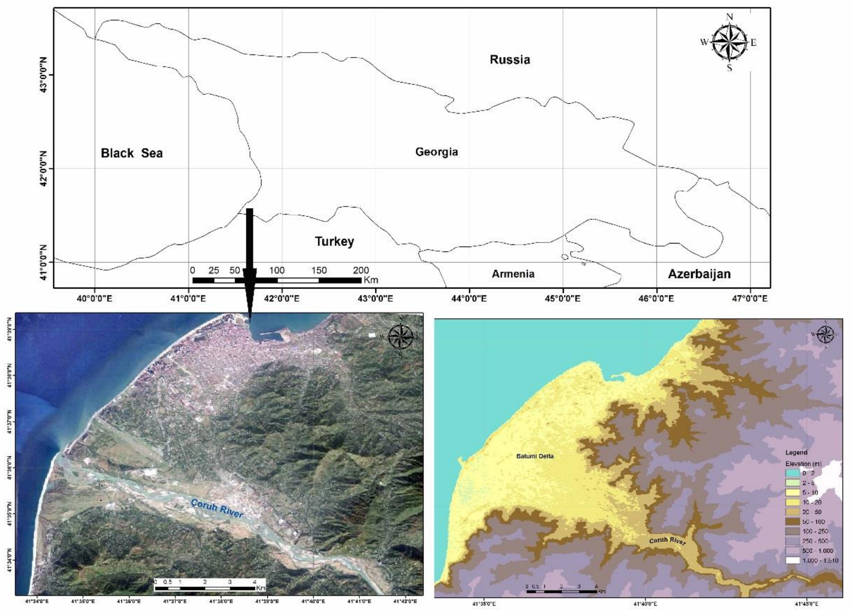

Figure 1: Location of the Batumi delta, and digital elevation model (DEM) of study area

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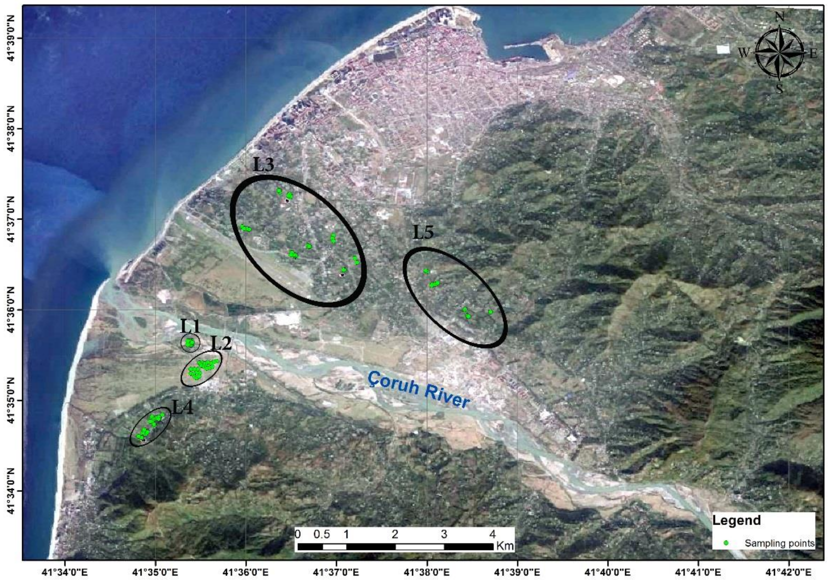

Figure 2: Location of the sampling points in the Batumi Delta (L1, L2, L3, L4 and L5 represent the sampling sites. L1 is located in active delta, L2 and L3 in lower deltaic plain, and L4 and L5 in upper deltaic plain)