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Anthropogenic impact on river basins: temporal evolution of sediment classes and accumulation rates in the northern Tyrrhenian Sea, Italy

by

Sergio Scanu*
Francesco Paladini de Mendoza
Daniele Piazzolla
Marco Marcelli

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Laboratory of Experimental Oceanology and Marine Ecology, Department of Ecological and Biological Sciences, Tuscia University, via Molo Vespucci, Civitavecchia 00053, Rome, Italy

Abstract

In this study, sedimentological and geochronological data from sections of a core (GRT50) collected in the Northern Latium coastal area were compared to data on pluviometric (rainfall) trends, river flows and the temporal evolution of human interventions in the three most important hydrographic basins (Mignone, Marta and Fiora) of this coastal area. The statistical analysis of pluviometric trends identified variations due to a decreasing trend in the Fiora river basin, whereas in the two other locations the decrease was not so significant. Data from the sedimentological analysis of the core confirmed a progressive decrease in the sandy component, which declined from about 30% to the current level of 7% over the last 36 years. There was no significant variation in the sediment mass accumulation rates (MAR), which were characterized by an almost cyclic trend that was probably determined by the most intense floods in the study area. The results revealed that the variations caused by the fluvial processes have affected the water runoff of the Fiora River, and that the consequent decrease in the sand production has been responsible for the recession of beaches in the coastal area between Tarquinia and Montalto di Castro.

Key words: river basin, sedimentation rate, anthropogenic impact

* Corresponding author: *sergioscanu@unitus.it*

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Introduction

The coastal sedimentary environment is strongly influenced by the dynamics of continental solid materials. Transport processes in coastal areas determine the distribution of materials that are derived from the surrounding basins through a complex series of interactions between the meteo-marine forcing, the physicochemical characteristics of sediments and the geomorphologic aspects of the coastal environment (Chiocci and La Monica 1996, La Monica and Raffi 1996, Paolocci and Siniscalchi 1996).

In this context, great importance is given to anthropic influences on the natural assets of hydrographic basins. These influences can affect the hydrological balance through the modification of such parameters as river flows, sedimentary production and runoff, which can be essentially attributed to providing the waterside accommodation, changes in the use of soil or modification of basins for hydraulic regimentation and electricity production (Baiocchi et al. 2008, Berriolo and Sirito 1985, Pagano et al. 2000, Leone et al. 2009, Grant et al. 2003, Magilligan et al. 2013, Bonelli and Pistone 1999, Vörösmarty 1997, Meybeck et al. 2005).

With regard to coastal sedimentology, these anthropic stressors can be explained through qualitative and quantitative changes in the sediments transported to the sea, and the consequent disturbances in the sediment balance and depositional rates (Engstrom and Wright 1985, Brush and Davis 1984, Vaalgamaa 2004). Human interventions in the processes that control the transport of solid materials, particularly the natural establishment of beaches, can occur by direct or indirect actions. Direct actions can be attributed to the construction of artificial reservoirs, which produce accumulation areas along the river that act as sediment traps (Grant et al. 2003, Magilligan et al. 2013), and prevent the natural flow of inert materials to the sea. Alternatively, the diversion of a hydrological network represents an indirect action.

This study investigated the possible reasons for the observed variations in the sediment accumulation rates, and determined the textural characteristics of samples through sedimentological and geochronological analysis of a coastal sediment core (GRT50). The study area was a coastal stretch between the Mignone and Fiora rivers in the northern Latium region of Italy, where a number of human interventions have been made since the 1960s, to modify the basins for agricultural purposes and water regimentation.

Materials and methods

Study area

The study area was delimited by the physiographic unit that extends from Capo Linaro to Monte Argentario in the northern Latium region of Italy (Fig. 1). The area receives alluvial deposits from the Fiora, Mignone and Marta river basins (Angelucci et al. 1979; Carboni et al. 1980; Tortora 1989a, b).

The seaward margin in this area, where the continental slope begins, is well defined and can be found at depths between 120 m and 150 m (Chiocci and La Monica 1996). The coastal sedimentation in the region is mainly controlled by the sediment contributions from the three most important rivers (Evangelista et al. 1996). The coast is dominated by sandy and sandy-pelitic sediments, which become increasingly silty-clayey in offshore areas due to the gradual dispersion of fluvial silt (Tortora 1989b).

Moving from the north to the south, the seabed becomes shallower, which is related to a wide sandy coastal area. The gradual slope of the continental platform increases and is particularly accentuated in the section between Sant'Agostino and Capo Linaro where there are rocky outcrops (Chiocci and La Monica 1996, La Monica and Raffi 1996). Sediment transportation along the shore appears to occur in a southeast to northwest direction (Anselmi et al. 1976, Berriolo and Sirito 1985, Noli et al. 1996), which is further confirmed by the course of the terminal sections of the Marta and Mignone rivers, and by the northern orientation of their small deltaic systems.

The northern area of the physiographic unit, where the core sample was taken, has only a small sand contribution from the Mignone and Marta rivers, due to the geological characteristics of these two basins, and the peculiar geomorphologic structure of the seabed, in particular the bathymetrical slope decreasing toward the north (Caputo 1988, 1993; La Monica and Raffi 1996; Scanu 2012).

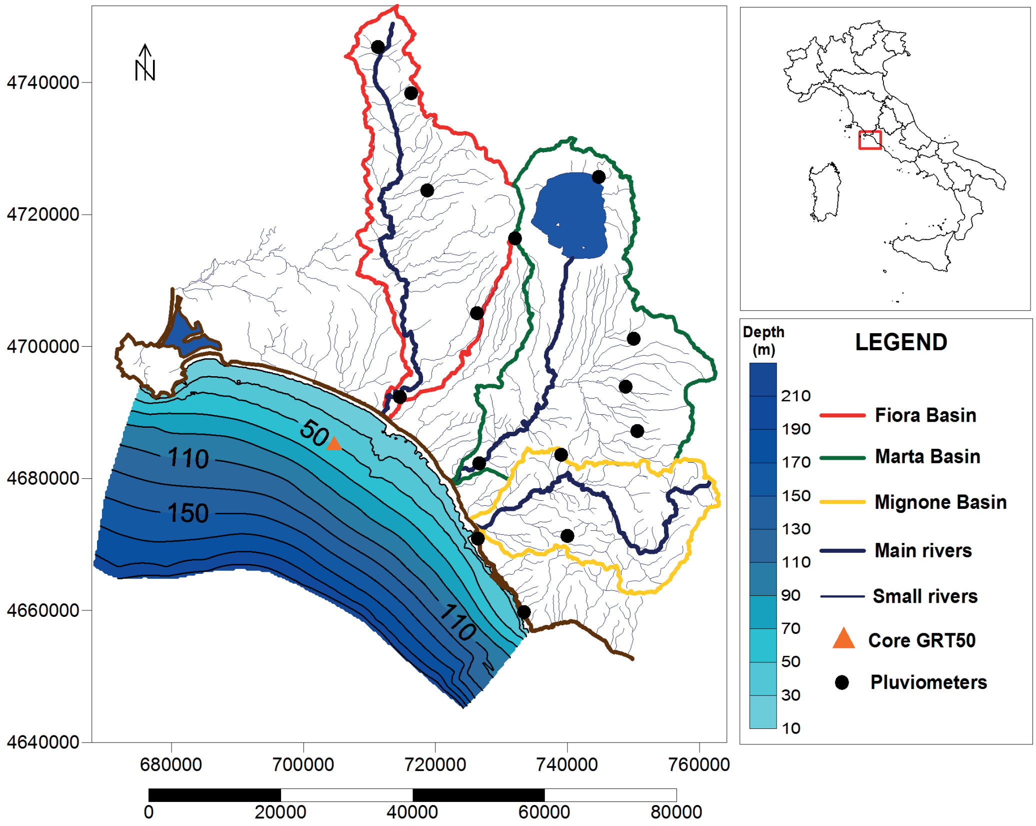

Fig. 1

Study area

The Marta river basin originates from Lake Bolsena. Volcanic formations cover about 50% of the basin; the remaining 50% is distributed between tuffaceous reliefs, lakes and marl. The sedimentary production is predominantly clayey for the volcanic formations and sandy for the tuffaceous formations.

More than half of the Mignone river basin is situated on hilly morphotypes (65%), in particular marl, arenaceous conglomerate, and clay. The sedimentary productivity are sandy for the conglomeratic formations and clayey for the clay and marl formations (Scanu 2012).

Regarding the Fiora River, the hydrographic basin is mainly situated on volcanic and tuff formations (43%), respectively characterized by a medium and high sedimentary productivity. Particularly, the sedimentary productivity appears to be clayey for the volcanic formations and sandy for the tuff formations (Spadoni et al. 2005, Scanu 2012).

Sedimentological and pluviometric data, and information regarding anthropic interventions for the three most important hydrographic basins (Mignone, Marta and Fiora) were collected to evaluate qualitative and quantitative changes in sediments of the reference coastal area.

Sediment sampling and analysis

The sediment sampling was conducted in summer (June-August 2011) by collecting the sediment core (GRT50) (approximately 20 cm length) using a UWITEC gravity corer (90 mm diameter) (Fig. 1).

To perform the geochronological analysis, the core was cut at 1 cm intervals immediately after collection. The sections were placed in sterile containers and stored at 4°C. The activity of ^{210}Pb in GRT50 core sections was determined at Flett Research (Winnipeg, Canada) by measuring the ^{210}Po granddaughter, based on a modified procedure (Eakins and Morrison 1978). Because none of the core sections had a depth sufficient to achieve ^{210}Pb background values, an additional analysis of ^{226}Ra activity was conducted. In this study, ^{226}Ra was determined by measuring the emanation of ^{222}Rn through a procedure described by Mathieu et al. (1988).

For particle size analysis, subsamples of the core section were prepared. All of the subsamples were sieved at 1 phi intervals (Folk 1974). The fraction finer than 63 μm was analyzed through the use of an X-ray sedigraph (Model 5100: Micrometrics, Norcross, GA, USA). The fraction finer than 63 μm was analyzed for sections 1, 5, 7, 10, 14, 15 and 17 of the core.

Pluviometric and river flow analysis

Pluviometric data were collected from the Latium Region Hydrographic Service, using all of the pluviometers in the three basins, which were registered since 1950 and reported in Table 1. Data were analyzed to determine if there was a temporal trend for any parameters. The trend analysis of the historical data series was performed using non-parametric statistical tests that could be used to identify individual characteristics of the data, in addition to environmental trends as described by Helsel (1987). Mann-Kendall (Mann 1945, Kendall 1975, Hirsch et al. 1982, Hirsch and Slack 1984) and Spearman (1904) rank correlation tests were used to analyze the average annual rainfall. The Mann-Kendall test is often used to search for monotonic trends in climatologic historical series (Sneyers 1998), while the Spearman rank correlation test can be used to determine trends when time is one of the two variants (Hipel and McLeod 2005). Through this analysis, it was possible to verify positive or negative trends in the historical rainfall data series. With regard to the Fiora river flow, the monthly data and the annual frequency, mean intensity, maximum and standard deviation of flood events were analyzed. The data were retrieved by the hydrological MOBIDIC model (Castelli et al. 2009) provided by the Fiora Basin Authority, which refers to the river mouth over the period of 1979-2010. Originally, a graphical representation was performed using a smoothing procedure (Locally Weighted Regression Smoothing: Cleveland 1979, Cleveland 1985, Chambers et al. 1983), whereas later the data were submitted to the Kruskal-Wallis test (Kruskal and Wallis 1952). Finally, the annual and monthly parameters were analyzed using the Mann-Kendall test. For monthly data, the Seasonal Mann-Kendall test was used to take into account the seasonal fluctuation of the river flow.

Table 1

List of present pluviometers in the considered river basins.

River basins	Pluviometers municipalities location
Fiora	Santa Fiora
	Selvena
	Canino
	Montalto di Castro
	Ponte di Pitigliano
	Valentano
Marta	Vetralla
	Monte Romano
	Bolsena
	Viterbo
	Barbarano Romano
Mignone	Allumiere
	Pantano
	Tarquinia
	S.S. Aurelia

Anthropic interventions in the basins

To evaluate the anthropic impact exerted on the rivers, information was collected regarding regimentation, derivation, dredging and the presence of dams, all of which could affect the liquid and solid transport. Data were provided by both the Basin Authority of the Fiora River and the Hydrographic Service of the Latium Region Water Resources. In addition, all of the previous studies regarding the water catchment along the rivers were collected and reviewed to obtain a complete and comprehensive overall picture of the basins. Moreover, data on the soil-use changes from the Corine Land Cover Project (www.isprambiente.gov.it) were collected to evaluate the changes between 1990 and 2006 in the landscape in the considered river basins. The Corine Land Cover (CLC) is a European Project for the soil-use assessment, monitoring, environmental protection and cartography. The first map was produced in 1990 and subsequently updated in 2000 and 2006.

Results

Pluviometric and river flow data

The annual pluviometric data for the three examined basins are presented in Figure 2. With regard to the Fiora and Marta rivers, a negative rainfall trend can be observed, while there were no variations from 1950 to 2012 for the Mignone River.

The statistical analysis revealed a negative trend in all three basins, which is confirmed by the ρ and τ values (Spearman and Kendall correlation coefficients in Table 2 and 3). However, the p-value was only statistically meaningful for the Fiora basin, while for the two other basins, the p-values cannot prove a real significant change in the rainfall. The flow evolution in the Fiora River, which is presented in Figure 3, has a negative trend from 1979 to 2010. The Kruskal-Wallis test and Seasonal Mann-Kendall test conducted on monthly data produced a p-value of $3.1641e^{-14}$ and 0.0041, respectively. Therefore, it can be confirmed that there were significant differences in the data for the studied period.

The Mann-Kendall test (Hirsch et al. 1982, Hirsch and Slack 1984), which was conducted on annual frequencies, averages, maximum intensity and standard deviation of flood events, revealed that there are no changes in the last 30 years of the flood regime of the Fiora River. The results of the trend statistics are presented in Table 2 for pluviometric data, and in Table 3 and Figure 4 for the river flow data.

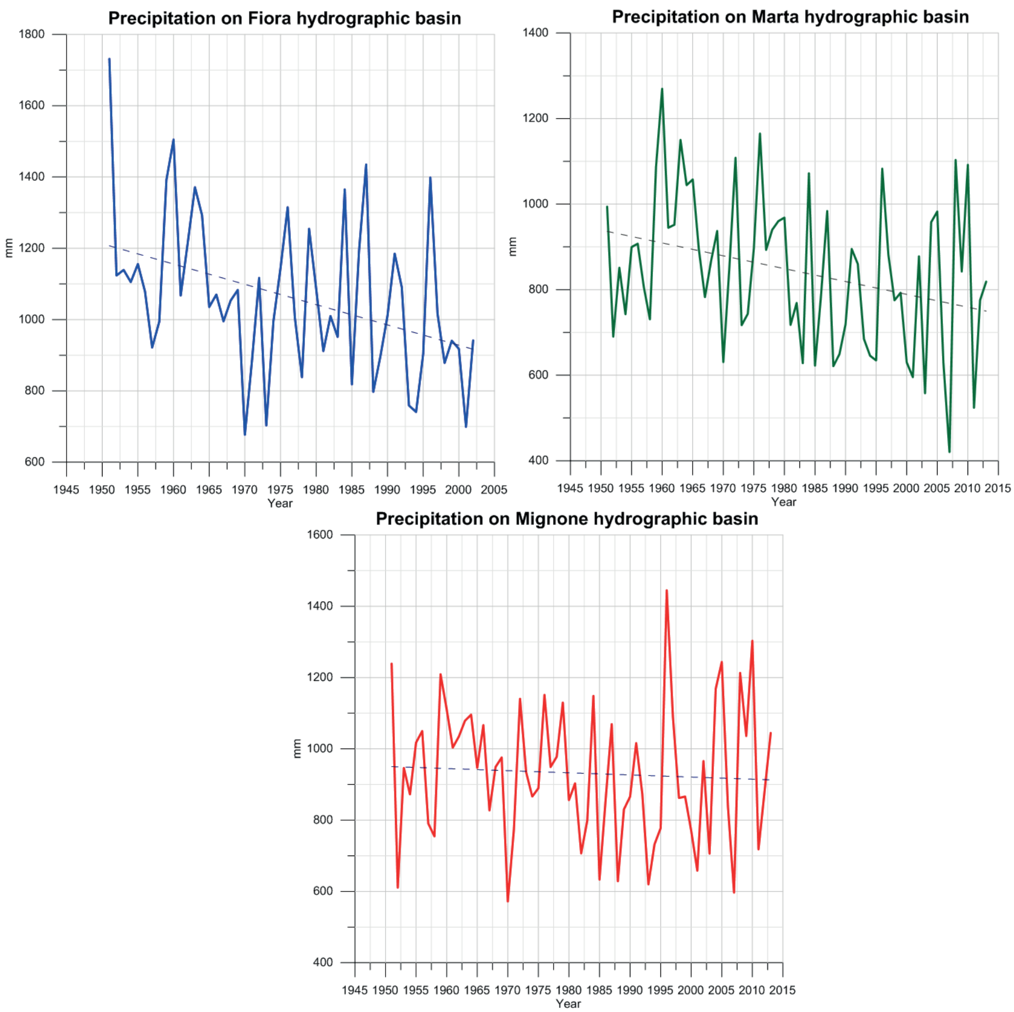

Fig. 2

Annual pluviometric data for the Marta, Mignone and Fiora river basins

Table 2

Result of Spearman and Mann-Kendall Tests for pluviometric data

Yearly means pluviometric data	Spearman-rho test		Mann-Kendall tau test	
	ρ	p-value	τ	p-value
Fiora basin	-0.4081	0.0029	-0.276	0.04
Marta basin	-0.2543	0.0502	-0.1785	0.0445
Mignone basin	-0.0754	0.5659	-0.071	0.4328

Table 3

Result of seasonal Mann-Kendall Test for river flow data

Montly means Fiora river flow	Seasonal Mann-Kendall test	
	τ	p-value
	-0.235	0.0041
	Mann - Kendall test	
Floods averages	0.113	0.3724
Floods maxima	-0.012	0.9354
Floods frequencies	-0.19	0.1285
Floods standard deviation	0.042	0.7448

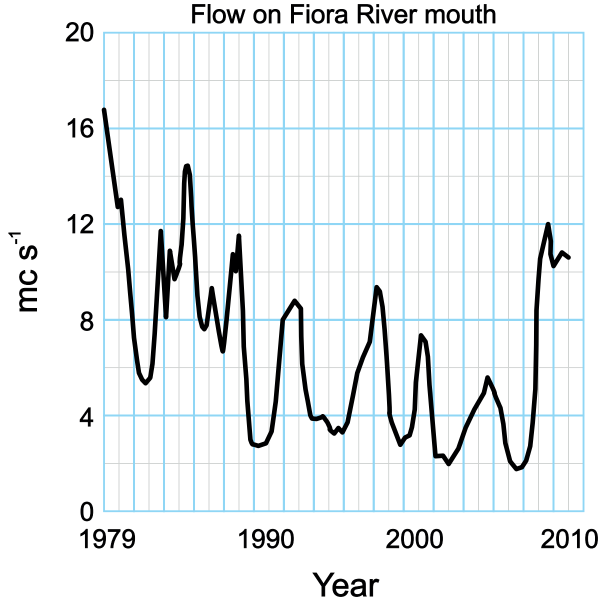

Fig. 3

Fiora river flow evolution

Soil-use changes

Table 4 shows the percentage cover of each class in the three river basins in time. The land cover analysis of the three hydrographic basins shows an important human impact that reaches up to 80% of the Marta basin, as it can be concluded from the

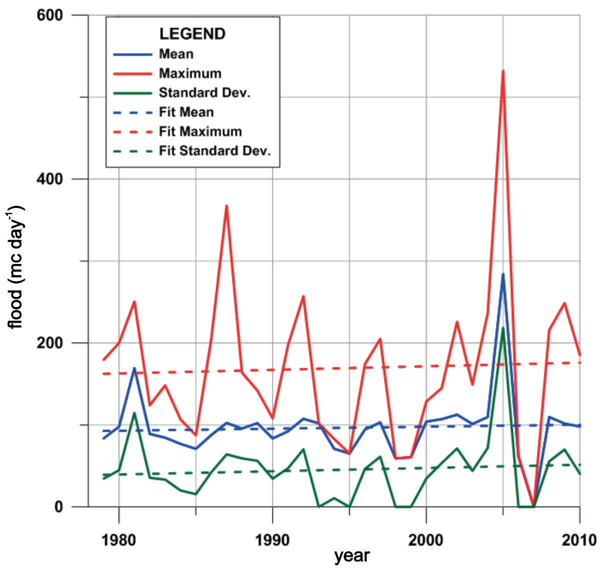

Fig. 4

Statistic results of the Fiora river flow analysis

percentage cover reported in Table 4. The Fiora and Mignone basins have a similar soil-use percentage for anthropic activities (50-60%). Except for the Marta basin, the artificial soil increased at the expense of natural soil by approximately 6-10%. In particular, the largest difference is observed in the Fiora basin (10%) where anthropic activities have expanded to an area of about 85 km^2. Detailed analysis for the Fiora and Mignone river basins revealed that the main changes involve crops and arable crops at the expense of dense forests.

Radionuclide measurements and the mass accumulation rate

Measurements of ^{210}Pb can be used to estimate the age of sediments and sedimentary mass accumulation rates (MAR) (Goldber 1963, Koide et al. 1972, Appleby and Oldfield 1978). In this study, the Constant Rate of Supply (CRS) model was applied: (Appleby and Oldfield 1983, Robbins et al. 1978). Measurements were supplemented with measurements of the ^{226}Ra activity, for the estimation of ^{210}Pb background values.

The ^{210}Pb activity profile of the core displayed an irregular, but approximately an exponential decrease as a function of depth (Fig. 5). The maximum activity of 15.49 dpm g^{-1} recorded in section 4 was about twice the lowest activity of 6.83 dpm g^{-1} recorded in

Table 4

Soil use changes in the considered river basins

River basin	Soil use	% Coverage		
		1990	2000	2006
Fiora	Areas with sparse vegetation	0.278	-	-
	Mining areas	0.079	-	0.119
	Agricultural crops	7.628	8.808	-
	Dense forests	34.965	36.732	25.710
	Coniferous forest	1.338	0.901	1.051
	High bush	3.497	2.953	3.315
	Crops	9.217	7.867	16.913
	Arable crops in non-irrigated areas	32.194	34.285	43.040
	Urban fabric	0.767	0.919	0.705
	Olive groves	4.061	2.247	3.506
	Vineyards	0.143	0.529	0.562
	Meadows	4.929	4.328	4.597
	Inland wetlands	0.047	0.033	0.034
	Orchards	0.037	-	-
	Pastures	0.822	0.292	0.450
	Artificial soil	**54.947**	**54.948**	**65.294**
	Natural soil	**45.053**	**45.052**	**34.706**
Marta	Areas with sparse vegetation	0.006	-	-
	Mining areas	-	-	0.006
	Agricultural crops	7.389	8.463	-
	Dense forests	14.264	12.252	14.260
	Coniferous forest	0.203	0.031	0.282
	High bush	1.480	1.441	1.681
	Crops	9.118	9.280	17.292
	Arable crops in non-irrigated areas	51.221	50.993	49.800
	Urban fabric	1.994	1.612	2.358
	Olive groves	11.061	11.885	10.380
	Vineyards	-	0.094	0.066
	Meadows	0.673	0.652	0.716
	Orchards	-	0.640	0.723
	Pastures	2.460	2.435	2.436
	Low bush	0.129	0.223	-
	Artificial soil	**83.244**	**85.402**	**83.061**
	Natural soil	**16.756**	**14.598**	**16.939**
Mignone	Areas with sparse vegetation	0.057	-	-
	Mining areas	-	-	0.032
	Agricultural crops	8.433	9.077	15.497
	Dense forests	30.476	31.077	25.874
	High bush	9.315	11.125	11.983
	Crops	8.272	6.500	-
	Arable crops in non-irrigated areas	35.238	32.392	38.464
	Urban fabric	1.247	1.339	0.849
	Olive groves	-	0.058	0.058
	Meadows	2.521	2.359	2.254
	Orchards	0.098	0.927	0.857
	Pastures	2.899	2.921	4.133
	Low bush	1.443	1.993	-
	Areas hit by fire	-	0.233	-
	Artificial soil	**56.187**	**53.446**	**59.889**
	Natural soil	**43.813**	**46.554**	**40.111**

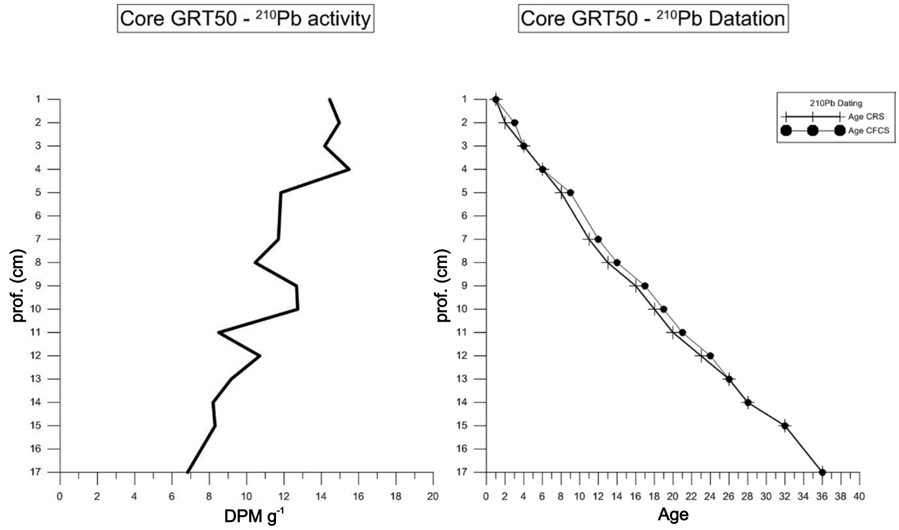

Fig. 5

^{210}Pb activity profile of the core sample

the bottom section. The dry bulk density of the core generally increased with depth (range = 0.484–1.057 g cm^{-3}). The activity of ^{226}Ra was 1.58 and 1.73 dpm g^{-1} in the 5–6 cm section and the 15–16 cm section, respectively. The net unsupported ^{210}Pb activity was calculated by subtracting the nearest neighboring ^{226}Ra measurement from each total ^{210}Pb value.

The ^{226}Ra activities measured at two depths indicate that the background ^{210}Pb activity level was not reached in this core.

When applying the linear regression model, it was assumed that the input of ^{210}Pb and the sediment accumulation rate were constant. Although some variation in the sediment accumulation rate was apparent, the linear regression model was applied to the complete profile because it appeared that the average sediment accumulation rate was reasonably well estimated. The CRS model assumes a constant input of ^{210}Pb and a core that is long enough to include all measurable atmospheric ^{210}Pb. Because the second assumption was not satisfied in this core (i.e. the background level was not reached), it was not possible to apply the CRS model. However, it was possible to calibrate the CRS model against the linear regression model, and therefore allow the CRS model to be used. The total atmospheric ^{210}Pb inventory (dpm cm^{-2}), required in the CRS model calculation, was selected (199.45 dpm cm^{-2}) so the average sediment accumulation rate in sections 1-17 in the CRS model matched exactly the average accumulation rate (0.4111 g cm^{-2} per year) calculated by the linear regression model. With the CRS model calibrated, it was then used to calculate the age of the bottom of each section in the core.

There was some variability in the individual sedimentation rate for each section (Fig. 6), with the maximum (0.5 g cm^{-2} per year) at the beginning of the 1990s and the minimum (0.33 g cm^{-2} per year) at the end of the 1980s. Temporal evolution of the accumulation rates occurred over the last 36 years.

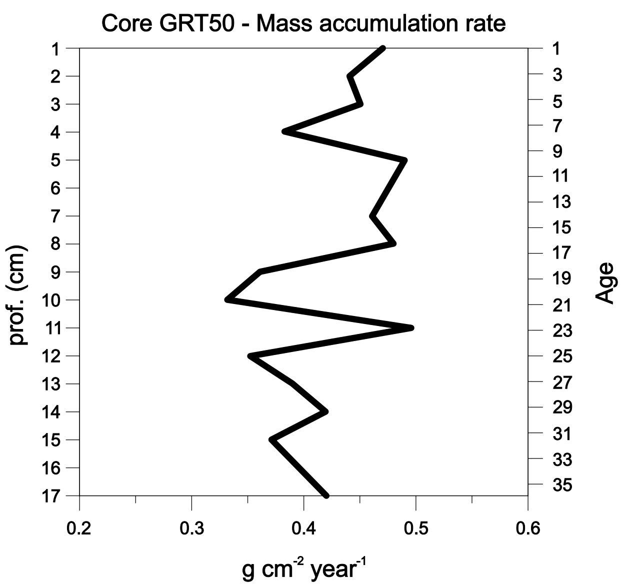

Fig. 6

MAR of GRT50 core sample

Sediment classes

The results of the grain size analysis of the core sections are presented in Table 5 and Figure 7.

The results show a change in the textural class in the last 36 years (sediment changes from silty clay to loam), with a consequent decrease in the sandy particle size fraction from about 30% 36 years ago to the current value of about 7%. The trend in the percentage sandy fraction presented in Figure 7 indicates a nearly constant decrease, with some variation in the 1990s.

Table 5

Sediment class evolution in GRT50 sections

Sections	Sand	Silt	Clay	Sediment classes
GRT50_1	7	39	54	Silty clay
GRT50_5	11	37	52	Silty clay
GRT50_7	17	36	47	Silty clay
GRT50_10	15	34	51	Silty clay
GRT50_14	21	31	48	Silty clay
GRT50_15	24	29	47	Loam
GRT50_17	31	26	43	Loam

Discussion

Since the 1920s, the hydrographic basins of the study area have experienced a large anthropic effect that is evident in both the variation in the soil use and the direct human interventions in the river beds.

Falls and dams in the river beds, associated with the hydroelectric power generation, occurred from 1920 to 1965, while since 1960, the rivers in these basins have often been diverted to provide irrigation, with consequent decreases in the flow. Occasionally, the flow has fallen below the minimum sustainable outflow as observed in the Marta River in 2005 (Baiocchi et al. 2008). Table 6 shows the full list of human interventions, which have been made for different reasons along the river beds of the Fiora, Mignone and Marta hydrographic basins, and which were registered in 1999 and in 2013 by the Basin Authority of the Fiora River and the Lazio Region, respectively. The analysis of the soil use shows that the human activities increased by 6-10% over the available time steps in the Fiora and Mignone river

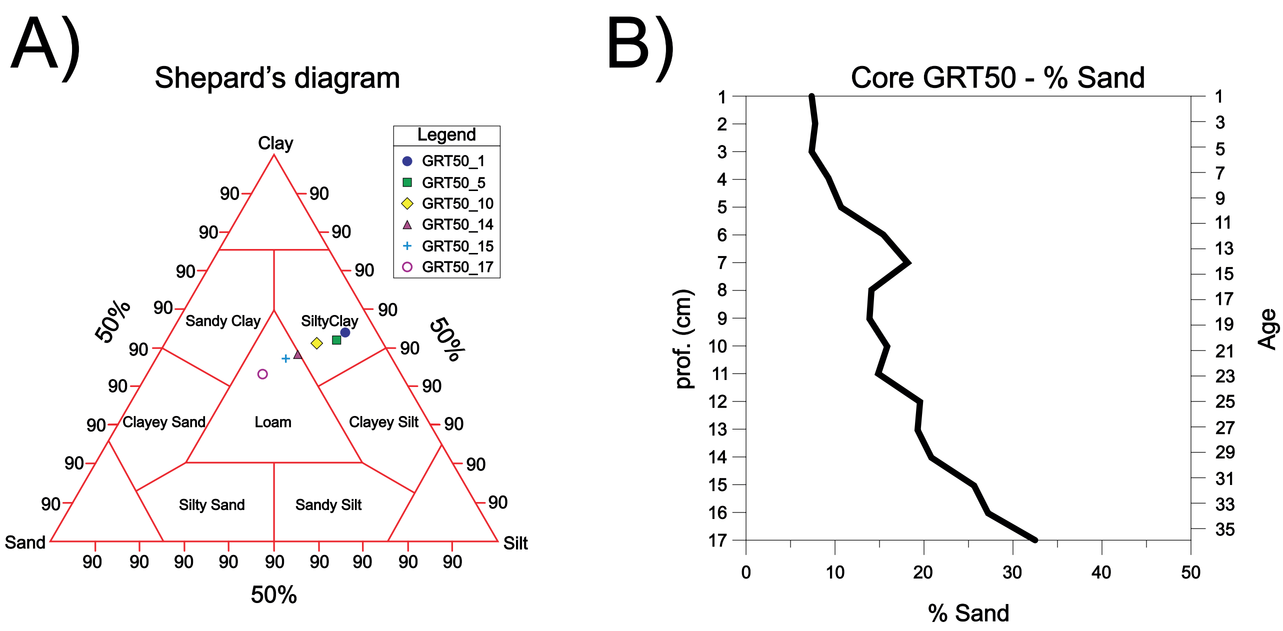

Fig. 7

Grain size analysis results for the GRT50 core. Sediment class evolution (from loam to silty clay) (A) and constant decrease in the sandy fraction (B) in the last 36 years

Table 6

List of interventions along Fiora, Mignone and Marta hydrographic basins

Hydrographic basin	Use	Number	Flow (l s^{-1})
Fiora	Irrigation	55	1360.91
	Zootechnical	1	1
	Hydroelectric	3	2300
	Drinkable	9	2830
	Individual	4	25
	Fish farm	1	10
	Other use	2	10,6
Marta	Flow rate relulation	1	0
	Hydroelectric	5	11126
	Irrigation	1	2850
	Hydromechanic	1	2143
Mignone	Thermal	1	95
	Irrigation	1	30

basins (Table 4). The Marta river basin has a strong human impact with more than 80% of the artificial soil cover. This condition has been observed since 1990 and no significant changes occurred in the last 16 years. The largest variation is observed on the Fiora basin (10%) where anthropic activities have expanded to an area of about 85 km^2. Detailed analysis for the Fiora and Mignone river basins revealed that the main changes involve crops and arable crops at the expense of dense forests, favoring the water catchment for irrigation purpose.

Previous studies undertaken by the Basin Authority of the Fiora River (Bonelli and Pistone 1999) have shown that this river has lost most of its natural characteristics due to many human interventions and the extension of the hydraulic network.

The analysis of data provided by the Basin Authority of the Fiora River revealed that the superficial outflow of the Fiora River was affected by water withdrawal to such an extent that a negative hydrological balance occurred in winter, and was even more severe in summer.

The hydrological deficit was first verified in 1993, and was caused by many water withdrawals along the river beds that form the hydrological network of the Fiora basin. In summer, water abstraction for irrigation results in a 58% reduction in the normal water flow. In other periods, the reductions were clearly lower: 5.4% from October to May and 9.7% as an annual average (A.d.B. Fiora 2005).

A report by the Tuscany Region in 2004 identified a continuation of the hydrological deficit with a water abstraction of 22.121 m^3 year^{-1} taken from the Fiora River. The Marta River is the main outflow from Lake Bolsena. Since the 1960s, an artificial regimentation of the outflow has been conducted through the construction of gates in Ponte Della Cartiera by the Ente Nazionale per l'Energia Elettrica (ENEL) power company, to ensure a minimum flow for the operation of the S. Savino hydroelectric power plant. Therefore, the river flow can no longer be considered natural (Pagano et al. 2000). Furthermore, many derivations have produced an alteration in the natural river outflow, and although the hydrological balance indicates that the superficial runoff waters are 30% of the total hydrological resources, the superficial outflow would be 20% higher without irrigation withdrawals (Baiocchi et al. 2008). The flow data of Centrale Traponzo revealed that the annual average flow has decreased from about 100 to 40 m^3 year^{-1} since 1950 (Leone et al. 2009). In this context, even the water withdrawals in Lake Bolsena have to be considered. According to the previous studies (Pagano et al. 2000) conducted in 1960–1990, the deficit was estimated at 65.5 m^3 year^{-1} compared to 20 m^3 year^{-1} estimated in 1931 and 1960.

The Mignone River has also been affected by human interventions that are considered to be less important in terms of the quantity of water withdrawn. There are no data available regarding the flow in recent decades, but data for withdrawals indicate that even for this river an alteration of the flow has occurred, albeit to a lesser extent.

The direct action regarding the solid transport has been conducted through the withdrawal of inert materials over a decade (1975–1985), but this is no longer the case.

Concerning the sedimentological and geochronological data, the change in MAR observed in the GRT50 core indicated that in the marine environment, adjustments to the hydrographic network of the basins did not change the quantity of their overall contributions, but did lead to a progressive change in the textural ratios. The effect of dams on the reduction in transport of solid material, which replenishes natural beaches was emphasized by recent silting of the Vulci Dam (built in 1923) (Berriolo and Sirito 1985, Bonelli and Pistone 1999). This was not detected in the core sample, but was reflected by the dramatic decrease in the sandy fraction, which declined from 30% to about 7% over 36 years, with a total decrease of 400% (Fig. 7).

There was a slight increase in MAR over the study period, as it appears from the GRT50 core results. The same slight increase is visible in the annual regime of floods, both for the average and the maximum flow (Figure 4). The slight increase in MAR values recorded in the core GRT50 can be explained by the lack of variation in the flood regime. Moreover, changes in the soil use and building of dams and water catchments for the irrigation purpose could have affected the sustainability of the river.

Conclusions

Over the period considered in this study, the synergistic action of several factors has produced variations in the textural ratios of materials in the offshore area of the Fiora delta, as presented in Table 5.

However, it was confirmed that the coastal area is still characterized by sandy sedimentation that occurs up to a bathymetric depth of 50 m, which confirms previous data reported for the geomorphologic and sedimentary characteristics of this part of the continental platform (Chiocci and La Monica 1996).

The qualitative and quantitative changes observed through the analysis of the GRT50 core are consistent with the previously reported data that indicated a regressive trend in the coastline, which is still ongoing and particularly strong along the coast of Montalto di Castro and Tarquinia (Berriolo and Sirito 1985, Regione Lazio 2013).

Human interventions that lead to changes in the water flow have an indirect consequence on the transport of solid materials because reduction in the liquid flow will decrease the sustainability of the river (Vörösmarty 1997, Meybeck et al. 2005). In general, an increase in the fine fraction is related to changes in the soil use (Brush 1989, Appleby and Oldfield 1983, Engstrom and Wright 1985) with a subsequent increase in the runoff (Brush and Davis 1984). A likely influence on the average river flow could be reflected in a progressive decrease in the annual rainfall (Fig. 2), which was particularly apparent in the Fiora basin. Even though the average flow of the Fiora River has decreased, the flood regime remained unaffected over the past 30 years justifying the MAR.

In a broader context, it is known that precipitation in the Western Mediterranean is strongly influenced by cyclones and global atmospheric patterns, in particular during winter, by the North Atlantic Oscillation (NAO) (Hurrell 1995, Dai et al. 1997). The negative NAO state is responsible for positive precipitation anomalies over most land areas in the Mediterranean Region and the association between the structural characteristics of cyclones and NAO was demonstrated by Trigo et al. (2000).

As observed by Maheras et al. (2001) and Trigo et al. (2000), the cyclones have decreased in the Western Mediterranean Sea and in the same way, the Mediterranean average winter precipitation has decreased during the last fifty years by about 20% with the decrease occurring mostly during the period 1970-1990 (Mariotti and Struglia 2002, Reale and Lionello 2013).

In this work, the rainfall analysis shows a negative trend in the Fiora and Marta basins, while in the Mignone basin, this trend is not significant. The data are therefore consistent with the general trend observed in the Western Mediterranean area. In this context, the anthropogenic impact may not be the only driving factor of the observed textural variations, although the strong impact of human activities (more than 60% of the artificial soil use) observed in the river basins and the relative variations over the last 16 years (Table 4) added to the history of human intervention directly in the riverbeds, could have produced the textural variation observed on the core samples. However, the acquired data suggest a progressive change in the quality of sediments arriving in the coastal area, with a clear trend for an increase in the pelitic percentage over the sandy fractions.

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