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Interaction between Catchment Basin Management and Coastal Evolution (Southern Italy)

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ABSTRACT

The research highlights the consequence of an imbalance between "basin management scale" and "coastal management areas" and investigates the relationship between coastline erosion and natural evolution of the inland system at the short-medium timescale while taking account of local climatic changes and sea level rise.

The study was undertaken in the Bradano and Basento catchment basins, on the Ionian coast of Basilicata Region (Southern Italy) through an institutional agreement between ENEA (the National Agency for New Technologies) and the Italian Ministry of Environment. In this area previous studies highlighted an important erosional coastline trend that began about 1950. No previous study has considered the role of the coastal river catchment area in this erosion.

With this aim, contemporary data for coastal and inland evolution were gathered and compared, implementing existing knowledge with land use analysis in the Bradano and Basento basins using multitemporal Landsat TM Images. For the coastal zone, the analysis was carried out at a more detailed scale using different cartographic sources mainly at 1:10.000 scale spanning the past 45 years.

The hydrographic network data was analysed to consider fluvial solid transport, dams, locks, and historical precipitation data series. The land use changes analysis has focused on inland features related to the desertification process, rainfall intensity and climatic changes. These features have been analysed mainly in relation to their contribution to soil erosion and subsequent sediment supply availability. Analysis of the coastline focused on changes in beaches, dunes and backshore areas.

ADDITIONALINDEX WORDS: *Ionian Sea, Basento and Bradano Rivers, Inland Changes, Solid transport, Erosion, Vulnerability.*

INTRODUCTION

Research on the relationship between coastal evolution and basin management is ongoing. This study is based on the Ionian coastal zone and, in particular, the segment between Bradano and Basento river mouths, covering a coastal length of 6.4 km.

The study area is in the Basilicata Region, where the need for coastal managementis based on the highest coastal erosion rates in Italy. Furthermore, the Basilicata Ionian coast lacks hard engineering structures and no general integrated management exists for regional or local authorities with a coastal management remit.

Analysis of this coastal system requires the important contribution from river catchments to be considered.

The aim of the research is to identify factors that control coastal erosion, to investigate relationships between catchment modification (river solid transport changes, catchment modification and, human settlement) and coastal evolution, to conduct new surveys and utilise multitemporal image processing techniques.

The present work is the first step in a general study whose final goal is the quantification of the role of catchment-coast interactions on coastline erosion. The system evolution is described on the basis of a literature review.

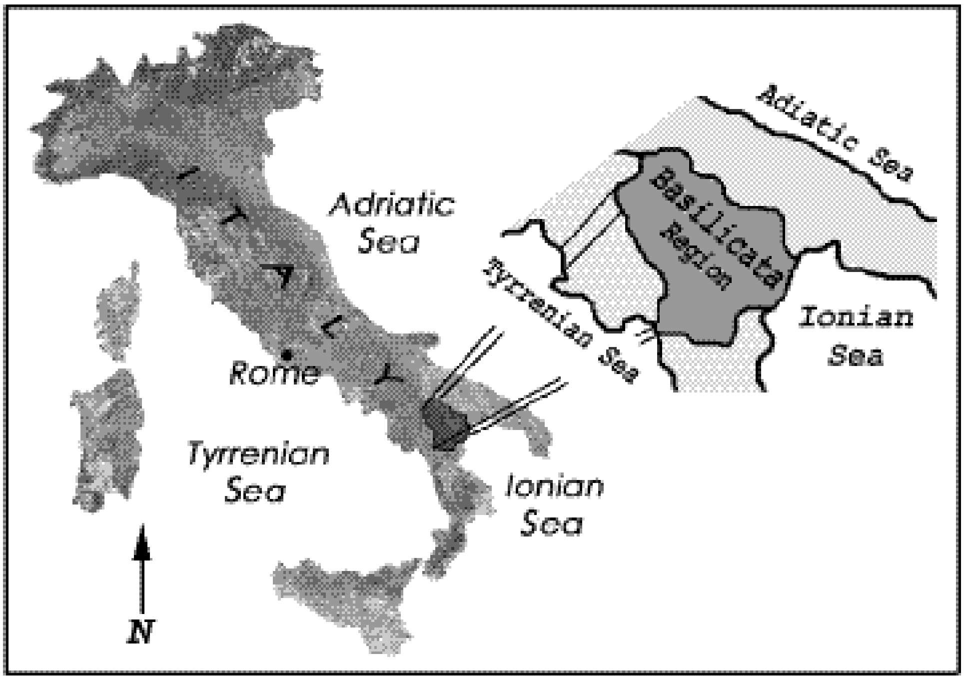

Figure 1 Basilicata Region location.

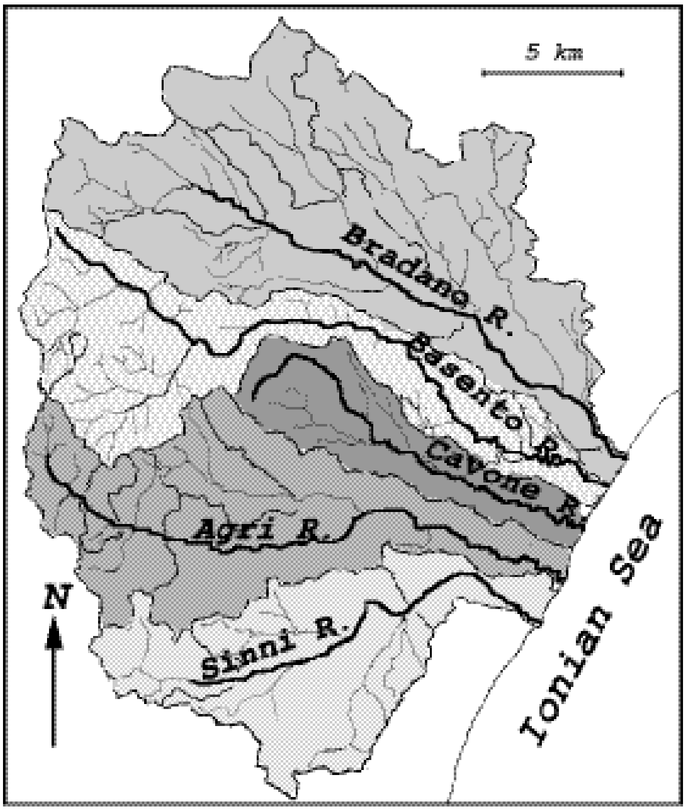

Figure 2 Sinni, Agri, Cavone, Basento and Bradano rivers catchment.

STUDY AREA CHARACTERISTICS

Basilicata Region, about 9992 Km^2, is located in southern Italy (Figure 1); its coastline faces both theIonian and Thyrrenian seas. The Ionian coast side is a flat continuous fine-sand beach backed by dunes and beach ridges covered by a thick pinewood. At the back of these environments is a wetland zone that was reclaimed since the 1950s. All the main rivers crossing the region (Sinni, Agri, Cavone, Basento and Bradano) flow into the Ionian sea (Figure 2). Their catchment basins are very large and are generally over 1300 km^2. The present study considers the coast between two main rivers: Bradano and Basento and their respective catchments.

Basento River has a catchment area of 1550 km^2. Bradano river has the largest catchment area (2750 m2) and cuts into Miocenic turbidites and Meso-Cenozoic clay deposits, while the middle part cuts Plio-Pleistocenic clastic deposits. The lower reaches of the river cross Quaternary sandy-conglomeratic lithologies. Those two rivers have parallel courses, flowing first from E-NE to W-SW, then to the south-west perpendicular to the coast line which is orientated NNE-SSW.

The Ionian littoral zone has been studied by several researchers (COCCO, 1975; COCCO *et al*., 1978, 1986; COTECCHIA *et al*., 1967, 1969, 1971) whose aim was to reconstruct the palaeo-environmental conditions.

Some historical settlements assist in defining former shoreline positions: the 2500 year old ancient Greek Metaponto town is located 1 km landward of the present coast (COTECCHIA *et al*.,1971). Indications of coastline position 400 years ago is provided by coastal towers built close to the sea in the second half of XVI century.

METHODOLOGY

This study step is mainly based on collation of existing data, new data gathering on basin land use and on recent shoreline movements assessed through multitemporal image analysis, that permits analysis of the relationships between inland changes and coastline evolution. This requires the use of contemporaneous data from both basins and coastal area for comparative analysis. The time period considered was influenced by the carthographic and satellite data availability and accuracy. Several kinds of information have been used. Air photo images and cartography were integrated in order to define changes in the coastline. For the basin areas two Landsat TM images (August 1986 and 2000) were compared to define, by a multi-spectral analysis, land use changes and soil erosion. The European Union Corine land use database were used to complete the land use evolution analysis. To determine coastal evolution, 1947 black and white air photo images from RAF, 1949 National Military Geographic Institute cartography (at 1:25.000 scale), 1986 ortho photo images (Regione Basilicata) and 1999 Ortho photo images(Compagnia Generale delle Riprese Aeree) were georectified compared. Available fluvial sediment yield data was used to analyse potential changes in sediment discharge.

The result is a multitemporal analysis that permits quantification (considering the original data constraints) of coastline changes and the estimation of average rates of change, for different coastal segments and different time periods.

COASTAL EVOLUTION

The results indicate that coastal erosion is most rapid near the river mouth, whereas other areas vary between stability and accretion.

Between profiles1 and 2 (Figure. 3) the coastline retreated 116 meters (about 2.4 m/y) between 1947 and 1999 for a tract of 400-450 meters. The Basento River mouth moved about 200 meters (Figure 4) to the NE at about 3.8 m/y. Between profiles 2 and 3, erosion affected only the dunes because of a lack of beaches; the retreat on this tract is 113 meters (2.1 m/y). The beach was already eroding here before 1947 and dune ridges are still being eroded at present. Between profiles 3 and 5, the erosional trend decreased progressively although dune ridge erosion is still evident in this area.

Between profiles 5 and 6, after 1947, a tract of Metaponto Beach showed a progression tendency until the 1980s, that followed an inversion determining the Metaponto Beach erosional crisis.

The utilised data accuracy, tied to the scale maps, does not exclude the possibility that, into small tract, there are coastal nourishment. Those seasonal advancing are determined from sand supply coming from dunes dismantlement and cannot be considered how general littoral tendency variation sign.

Moving toward Bradano River (between profiles 6 and 7), long term stability is indicated. This net situation is, however, characterised by an accretional trend until 1949 (20 meters about), then stability up to 1986 and retreat until 1999 reaching again the 1947 shoreline position.. Between profiles 7 and 8 strong and progressive erosion is recorded since 1947 and at the profile8 the coast retreated by 72-74 meters (1.4 m/y). Strong erosion at point 9 caused beach narrowing of 32 meters between 1947 and 1949. The highest retreat in this tract is about 130 meters. Between profiles 9 and 10 the littoral exhibits maximum erosional impact: the coastline eroded by 267 meters and widespread dune erosion continues. Here, the beach width changed from 270 to 20 meters about in the last 50 years.

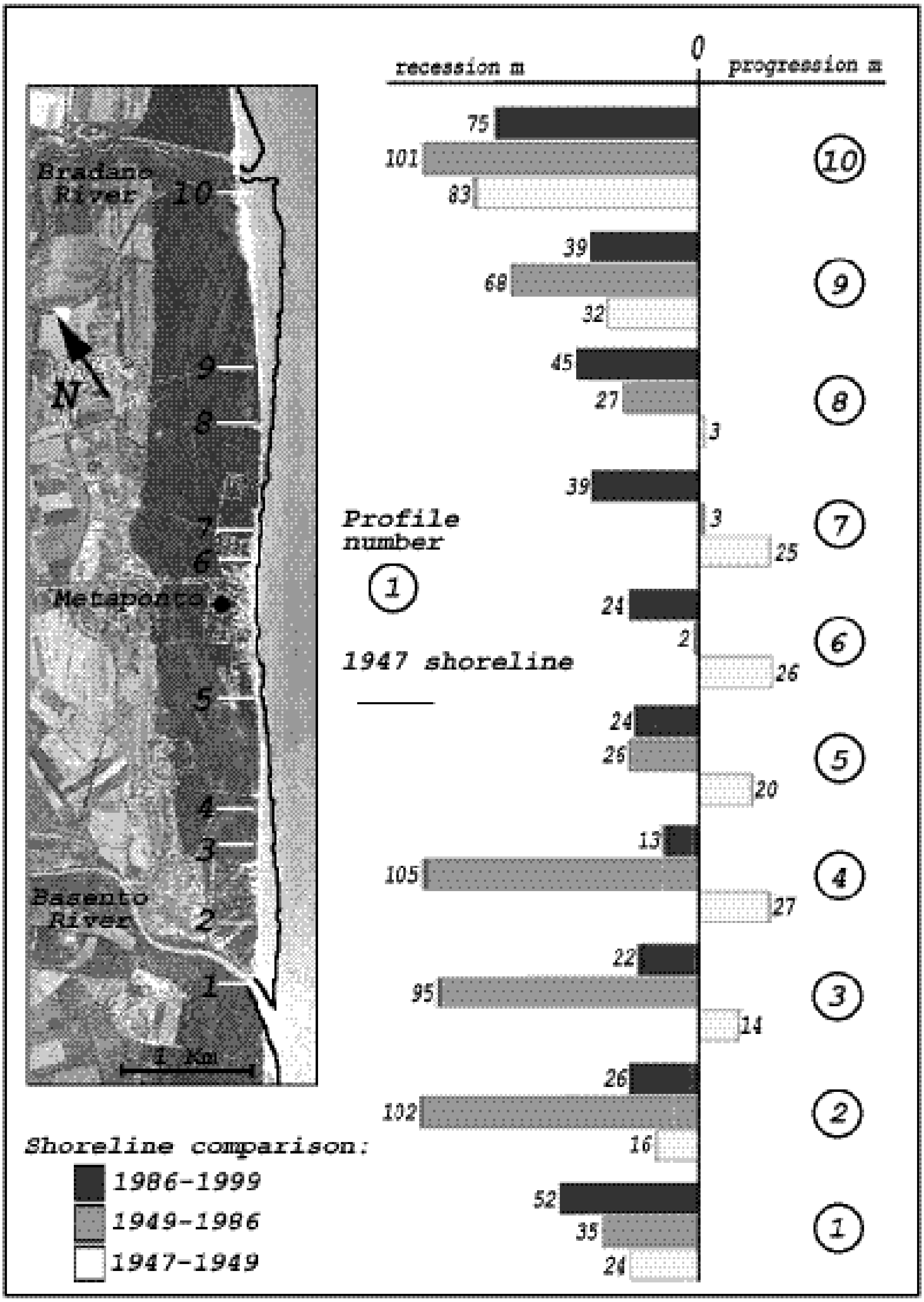

Figure 3 The block diagram shows the shoreline variations measured on the profiles during the last half Century, in the littoral tract between Basento and Bradano rivers.

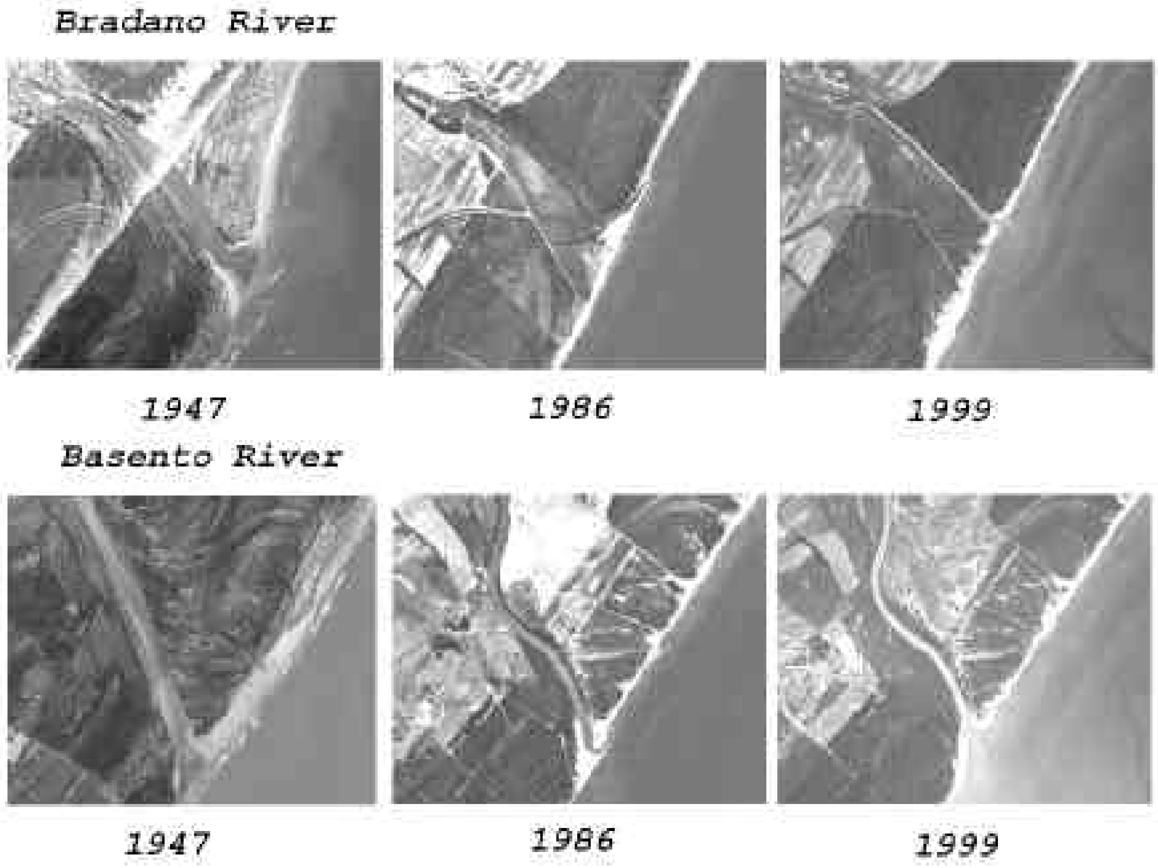

Figure 4 The anticlockwise rotation of Basento and Bradano river mouths between 1947 and 1999.

The Bradano river mouth moved 154 meters to the NE and retreated landward by 277 meters over the study period (Figure 4). At present, the coastline exhibits moderate accretion only in areas to the south of Metaponto town. All the remaining seafront is under erosion. A local erosion trend was also present before the period of investigation covered by this study as revealed from images and cartography analyses. before the 1950s dune ridges were being eroded close to the Basento river mouth left bank and Bradano river mouth right bank. The worst sea condition for dune erosion is probability caused from winds deriving from SE SSE , which produce high energy waves (COCCO *et al*.,1986). About 80% of the study area presently experiences rapid dune erosion. The main longshore sediment transport is toward the NE., Submarine canyons, located on the continental platform between the –25 and –50 meters isobaths trap some sediment moving alongshore.

HUMAN IMPACTS IN THE AREA

Numerous defence works have been undertaken on rivers flowing into the Ionic Sea in order to mitigate hydrogeological risks.

Five dams were built at the end of the 1950s (Table 1) in order to supply water needs.

Considering strictly the study area, a dam is present on the Basento River and is known as Camastra Lake. (Table 2). Two studies were carried out to identify sedimentation in Camastra Lake, using a lasertrack measuring instrument (MOLINO, 1993) and by image interpretation and comparison. The studies showed a solid transport reduction toward the sea of about 431 000 m^3/y in 29 years and an erosion rate in the catchment of about 1,2 mm/y.

In the Bradano catchment four artificial reservoirs have been built: S. Giuliano, Acerenza, Basentello and Genzano.

The studies between 1957 and 1959 showed an average sedimentation of 2,3 Mm^3/y, with an erosional rate of 1,44 mm/y in S.Giuliano Dam. In the following period, between 1959 and 1961, sedimentation decreased to 0.4 mm/y because of low precipitation and works on the dam. In 1977, studies showed a total sedimentation of 15,8 mm, identifying a rate of 790 000 m^3/y in a 20 years period and an erosion rate of 0.48 mm/y in the catchment. Other studies report a further increment of 4 meters between 1976 and 1978. From these data it is possible appreciate a great decrease in sediment yield from the river (Table 3).

Table. 1 Main dams present in the study area; Icold, « World Register of Dams», 1996

Body of water (dam)	River	Year	Kind of dam	Capacity 10^6 m^3	Area Km^2	Use
S.Giuliano	Bradano	1956	Gravity	107	1631	Irrigation
Acerenza	Bradano	1992	Hearth	47	142	Irrigation
Serra del C.	Basentello	1974	Hearth	41	267	Irrigation
Genzano	Bradano	1992	Hearth	57	36	Irrigation
Calastra	Basento	1970	Hearth	24	350	Industrial/drinkable

Table. 2 Sedimentation per year (average) into the basins (Spilotro *et al*. 1998.

Basin	River	Period	sedimentation average per year		Area Km^2	Erosional rate	
			m^3	T		mm	(Kg/m^3)
S. Giuliano	Bradano	1957/63	$2,35*10^6$	$3,29*10^6$	1 631	1,44	2,0
S. Giuliano	Bradano	1955/77	$0,79*10^6$	$1,11*10^6$	1 631	0,48	0,7
Camastra	Basento	1993	$0,30*10^6$	$0,42*10^6$	350	0,85	1,2
Calastra	Basento	1965/94	$0,43*10^6$	$0,60*10^6$	350	1,23	1,7

Table. 3 The solid transport data flowing into the Ionian Sea for equilibrated (0,5-1% river bed inclination) and not equilibrated (0,2-0,5% river bed inclination) river bed tracts (VIPARELLI, 1972).

Solid transport (Mm^3/y)	Sinni	Agri	Cavone	Basento	Bradano
Equilibrate river tract	6.5-25.5	11.5-16.5	14.5(average available only)	Not available	Not available
Not equilibrate river tract	25.5-12-4.5	16.5-9.5-4	14.5-7.5-3.5	Not available	Not available

A contribution to the coastal retreat comes also from river bed sand extraction which was particularly intensive between 1965 and 1992. Unfortunately a reliable volume estimation is very difficult to carry out, because the amount extracted was always greater than that permitted by licences. Between 1965 and 1977 official extraction of 8 Million m^3 from Basento River and 5 Million m^3 from Bradano, while between 1977 and 1992 1 Million m^3 from Basento and 900 000 m^3 were extracted from Bradano. It is important to remember again that the data are not complete and also that the real amount extracted could be multiplied by 5 to 10 factor compared to the real amount authorised, as for the main Italian rivers (DAL CIN, 1983).

Table. 4 Rain fall mm/y during the 1947-1990 period (CNR, 1993).

Year	Rain fall average mm/y	Years	Rain fall average mm/y	Years	Rain fall average mm/y	Years	Rain fall average mm/y
1947	1030	1957	1150	1967	1020	1977	730
1948	820	1958	860	1968	660	1978	1290
1949	650	1959	1680	1969	980	1979	1170
1950	930	1960	870	1970	830	1980	1070
1951	890	1961	900	1971	990	1981	1010
1952	830	1962	1000	1972	1120	1982	1760
1953	750	1963	910	1973	900	1983	870
1954	1100	1964	1070	1974	890	1984	1030
1955	1010	1965	890	1975	920	1985	650
1956	990	1966	1190	1976	1280	1988	780
						1990	230

CATCHMENT CHANGES

In order to identify the inland changes two Landsat TM images of August 1986 and 2000 were used. The whole part of the examined territory has been affected by land-use changes. The pinewood land changes are characterised by a decrease close to the right side of Bradano River, while close to the Basento River, a repopulation has taken place in the landward wood. A general erosion trend, although light, is however wide spread on the whole wood, however, it is not possible to appreciate major land-use changes in this sector.

Several small changes are evident in the maritime wood; the zone has high humidity and is heavily subdivided for agricultural use. This area is mainly under crop production equally divided between arable crops and vineyards Areas in the north-west have lower humidity and comprise arable land with small orchards. The area presents a dry landscape, and each kind of agricultural activity is developed on the slope. A complex of natural mountain woods is also developed on the top of the internal watershed. These woods are wild areas sited on inaccessible and high angle slopes.

Image analysis shows an increase of 30% in areas affected by desertification compared with the 1986 situation in the Bradano and Basento Rivers catchment. Analysing the precipitation historical data series shows an important rain fall decline over this period (Table4).

DISCUSSION

Coastal evolution is a complex phenomenon that reflects changes in sea-land and inland variables of which the coastline is a geoindicator.

The relationship between coastal evolution and inland areas (meaning basins flowing into sea) are not fully understood, and the significance of relationships changes from one site to another. The present study considers the particular case of Basilicata Ionian side were no hard engineering coastal defences exist and where the effect of climate and sea-level change on coastal evolution could be better considered.

From the data presented above it can be seen that no significant changes have occurred, in the basins of the two main Basilicata Region rivers (Bradano and Basento), in the period since the 1970s. Image processing however, shows a substantial increase in areas subject to desertification and associated erosion phenomena.

The changes in precipitation largely control this evolution of the mid- to upper catchment basins Bradano and Basento rivers.

Recent studies highlight in the Ionian show a stable or slightly falling relative sea level measures (Cabanes *et al*., 2001) indicate for a sea level trend in the same order as the instrument error. Thus sea level rise is not a major factor in coastal evolution in this region.

The climate change effects on the coastal zone should produce coastal accretion caused by a larger soil erosion and, consequently, a greater sediment supply from rivers. l. Instead, coastal erosional features characterise the beach dune system. The main changes that the study highlighted thus appear to relate to water management inside the basins.

Two main dams have been built on the inflowing rivers since the 1960s. These appear to trap the sediment necessary to maintain the coastline against sediment dispersal by littoral drift.

Immediately after dam construction years (1950-1980) the reduction in sediment supply caused erosion in the coastal areas, mainly adjacent to river mouths. In the following years the erosion phenomena become more widespread and involved progressively larger coastal segments.

Nevertheless, the erosion was also a pre-existing feature of these coasts, before the 1950s as revealed in historical maps.

At present, rivers and the coast operate as two independent systems. The lack of fluvial sediment supply means that coastal erosion patterns now reflect movement of a finite sediment volume and thus various stretches of beach interact with each other to produce a self-contained sediment budget. In this framework, where human interferences have isolated the coastal evolution from the basin evolution, it is clear that without artificial nourishment of the beaches, the coastal erosion trend will only continue. The erosion features, that have been highlighted in the coastal dune system, show the seriousness of the circumstances: the coastal dune is the last natural barrier along many kilometres of narrow beaches, along the Ionian littoral, and their destruction together with the crisis of the coastal aquifers, could cause an emergency state for the historical coastal pinewood.Some local evidence of coastal advancing are strictly related to the natural or anthropic coastal dunes dismantlement. It is very dangerous to evaluate this temporary nourishment how general coastal advancing sign. The opportunity to manage the coastal hinterland and coastline in an integrated way no longer exists since the two systems have been separated. The need for integrated coastal management is illustrated by the problems along the Ionian coast. It may be necessary to adopt some very hard policy choices like in Colorado river, where dams have been opened to force a "natural" beach nourishment. Italian policies for coastal zones should be based on detailed scale knowledge of real erosion susceptibility and risk, to determine risk mitigation strategies.

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