LONG-TERM IMPACTS OF HYDROPOWER DAMS ON COASTAL ENVIRONMENT- LESSONS LEARNED FROM DRINI RIVER

Kristi BEGO, Mihallaq QIRJO and Ferdinand BEGO
Department of Biology, Faculty of Natural Sciences, University of Tirana, Albania

---

ABSTRACT

GIS and satellite imagery analysis were used for the investigation of the long-term coastal dynamics in Drini-Lezha and Drini-Buna rivers, influenced by hydropower (HP) activity upstream of Drini River. Coastal habitats and riverine ecosystems of Drini-Buna and Drini-Lezha were mapped and classified based on their dynamics (1960 to 2014) when theHPs were constructed. The drastic changes of river flow and sediment regime have had an impact on the coastline dynamic, downstream river morphology, coastal habitat structure and quality. The progradation of both river deltas has stopped and the fronts have receded about 660m in Drin-Buna, and 604m in Drini-Lezha, with the island of “Franc Joseph” disappearing in the process. River length of main Buna and Drini-Lezha rivers have decreased as well. With a sedimentation budget several times lower than prior to HP construction, both deltas have become more susceptible to coastal erosion. The reduced river flow has led to the entrapment of fine sediments along the riverbanks which resulted in an increasingly narrower riverbed on both Buna delta river branches and Drini-LezhaRiver. Coastal habitats (dunes, estuaries, halophytic and brackish marshes, coastal lagoons) shrunk in their surface area, dunes being the most affected, losing 982 ha or 63% of their total surface between 1960 and 2014 in the Buna delta, and 123ha in the Drini-Lezha delta. Coastal erosion and narrowing of riverbeds have led to an increased incidence of floods with further socio-economic implications. Ecosystem resilience to climate change has decreased and flood prevention and management costs have increased. Reductions in size and quality of coastal lagoons and other wetland habitats have resulted in loss of species biodiversity, particularly in breeding colonial water birds. These changes have affected the ecotourism and recreational values of both deltas. All these adverse impacts and their associated costs not been taken into account during decision making, and the lack of cost-benefit analysis could affect HP development in other rivers of Albania as well, including Vjosa.

Keywords: GIS, Drini river deltas, HPP, coastal erosion, digital mapping, habitat dynamics

1. INTRODUCTION

The first HP dam in the Drini River watershed was built in 1971 at Vau i Dejes. Later on, three other dams were built upstream. Consequently, the majority of sediments produced within the Drini River watershed since 1971 have been trapped inside the HP dams, creating a negative budget of sediments discharged into the coastal area, causing an ongoing intensive coastal erosion in both river deltas (Bego *et al*, 2012; Le Tissier, 2013).

The effects of hydropower dams built along the rivers on the plain coastal dynamics have been documented by many authors worldwide (Collier *et al*, 1996; Milliman, 1997; Rosenberg *et al*., 1997 and 2000; Kowalewski *et al*, 2000; Sahagian, 2000). Hydropower dams and reservoirs trap sediments that in natural river's water regime are discharged and distributed along the coast, playing a vital role in coastal ecosystem stability and dynamics.

However, obtaining information and data to quantify long term impacts of such upstream interventions on the coastal ecosystem and biodiversity is a challenge for small countries. Remote-sensing has considerable potential as a source of information on the state and pressures on biological diversity and ecosystem services, at multiple spatial and temporal scales (Pettoreli *et al*., 2014a, b).

Remote sensing here usedprovideslong-term information and data aboutimpact of the construction of hydropower (HP) dams upstream to the state of wetlands and coastal habitats downstream in over 50 years, using Drini River as a case study.

2. MATERIALS AND METHODS

Study area

The figure 1 depicts the study area including the downstream section of Drini River and the Buna and Drini delta. Both deltas are created and influenced by the Drini River, the biggest river in Albania, whose watershed is shared among Albania, Montenegro, Kosovo and Macedonia.

The Drini River and its tributaries drain large terrains in the eastern, central and northern parts of Albania and neighboring countries (Montenegro, Kosovo and North Macedonia). The drainage basin comprises a total area of about 14,173 km^2(Kabo *et al*., 1990). The catchment basin of the Drini is five times smaller than that of the river Po, but its total annual sediment load has been calculated to be 15x10^{6}t/yr (Millimanand Meade, 1983; Milliman and Syvitski, 1992), 20 % greater than that of the Po. Pano *et al*., (1992) said that about 50 % of the total freshwater input from all Albanian rivers to the Mediterranean is provided by the rivers Drini and Buna. Milliman and Syvitski (1992) said that Drini River had a very high sediment yield (1200 t/km^2/yr) before the diversion measures.

Fig.2. Location of the Buna delta and Drini delta (the latter was the delta of Drini River, until 1831, time when Drini river changed its course towards north, joining with Buna River *via* Drinassa, but not fully abandoning its former river course towards Lezha (Source: Google Earth image of 2011).

The hydraulic regime of the Drini is characterized by occasional floods, caused by a combination of the predominantly torrential river dynamics with snow melt events and the influence of the karstic hydrography. The annual discharge of the Drini is 12,266 m^3/s (Pano and Avdyli 2009). However, due to artificial dredging and re-direction in 1958, only one third of the Drini's total discharge flows through Lezha today. The second distributary, now the main course, is called "Great Drini" (Drini i Madh) or the Drinassa and is connected with the Buna River (Bojana River).

Maps and scientific reports show that the Drini River changed its course and the location of the river mouth many times during history (Uncu 2011).

The flood damage potential of the Drini was partly reduced after drainage measures were introduced in the 1950s. Additionally, three dams were built along the river to harness electricity in the 1970s. These dams created big artificial lakes, with the most prominent being Lake Fierza (73 km^2). Nowadays, these lakes work as sediment traps – one of the main reasons why the sediment budget of the Drini and Buna delta is now negative.

Important wetlands and coastal habitats of Mediterranean and European Conservation interest are created in the estuarine and littoral zone of Drini's deltas, such as Velipoja and Viluni (Buna delta), and Kune-Vaine (Drini delta). All of them have been identified as Specially Protected Areas (SPA), Important Bird Areas (IBAs) and Emerald Sites, and are an important part of the network of the coastal Protected Areas in Albania.

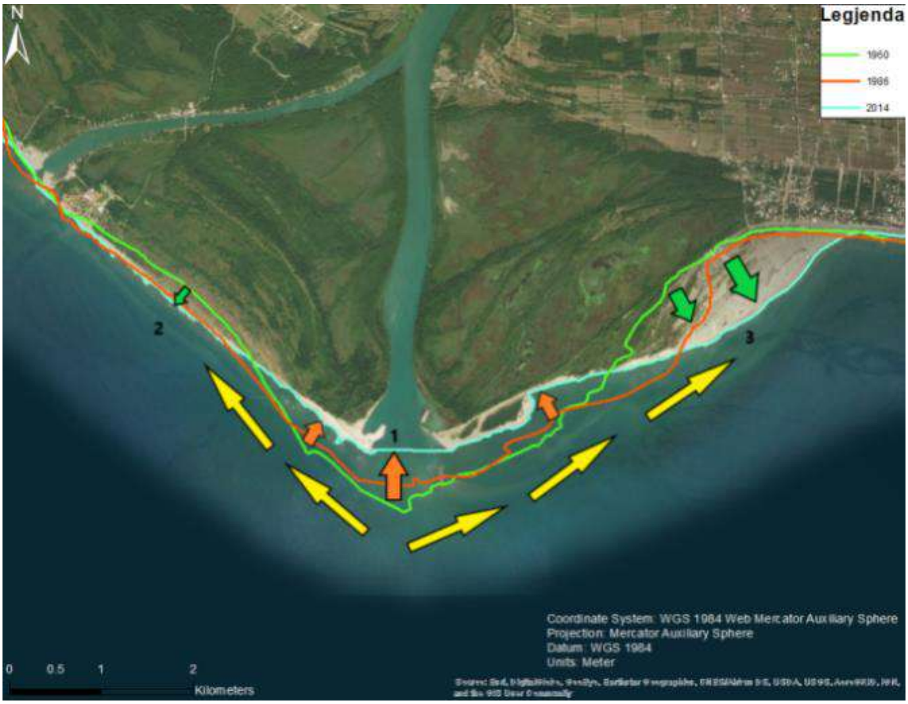
Methods

To stabilize the baseline map of the study area and their coastal habitats the oldest topographic maps of scale 1:25.000 of Albania produced by Russian cartographers were used. Those topographic maps are based on the images registered in the ’60s, before the construction of the first hydropower dam of Vau i Dejes in 1971 in the lower section of the Drini River. To measure the impact of the HP dams on both deltas of Drini River and their related coastal habitats we have processed the remote sensing imageries for the study areas from 2013 (provided by ESRI).

Digital maps for periods between 1960 – 2013 have been created using ArcMap 10.5, either through digitalization of old pre-existing maps, or through digital mapping based on satellite imagery available on ESRIs database. The study area and habitats found within were mapped and classified according to the Natura 2000 network. For agricultural lands and human settlements, we used identification codes in accordance with the EUNIS system for habitat classification. Furthermore, to assess the riverbank dynamics we measured the riverbed width over the years using remote sensing. Similarly, habitat dynamics over the study period were monitored using a combination of field surveys and remotely sensed information such as habitat surface area, composition, natural shifts and transformation. Field surveys have also been conducted for ground truthing and habitat classification purposes, in both Drini-Buna and Drini-Lezha deltas.

3. Results and Discussions

Data analysis shows that the Buna delta has a net gain of 191.8 ha in surface area since 1960. Compared to its progradation in 1900-1960during which the delta surface area nearly doubled (from 2100ha in 1900 to 4237ha in 1960), there is a clear indication that the construction of hydropower dams along Drini River in 1971 has disrupted this process. Reduced sedimentation and entrapment of sediment have exacerbated the intensity of coastal erosionin the Buna delta (Bego et al, 2012; Le Tissier, 2013; Faloutsos et. al. 2015), as well as Drini-Lezha delta (Boçi, 1994; Ciavola *et al*., 1995; Gjiknuri, 1995; Simeoni *et al*., 1997; Mathers *et al*., 1999; Fouache *et al*., 2001, 2010; Pano *et al*., 2003; Meçaj 2005). Consequentially, substantial coastline alterations are evident comparing imagery from the 1960-2014 timeperiod (Figure 2 and 3). In the last three decades, coastal erosion has led to the loss of "Franc Joseph" island, formerly situated at the very front of the Buna Delta (Dhora, 2017). *Part of the eroded material from the front of the delta gets redistributed along the shoreline, gradually leading to the flattening of the entire delta.*



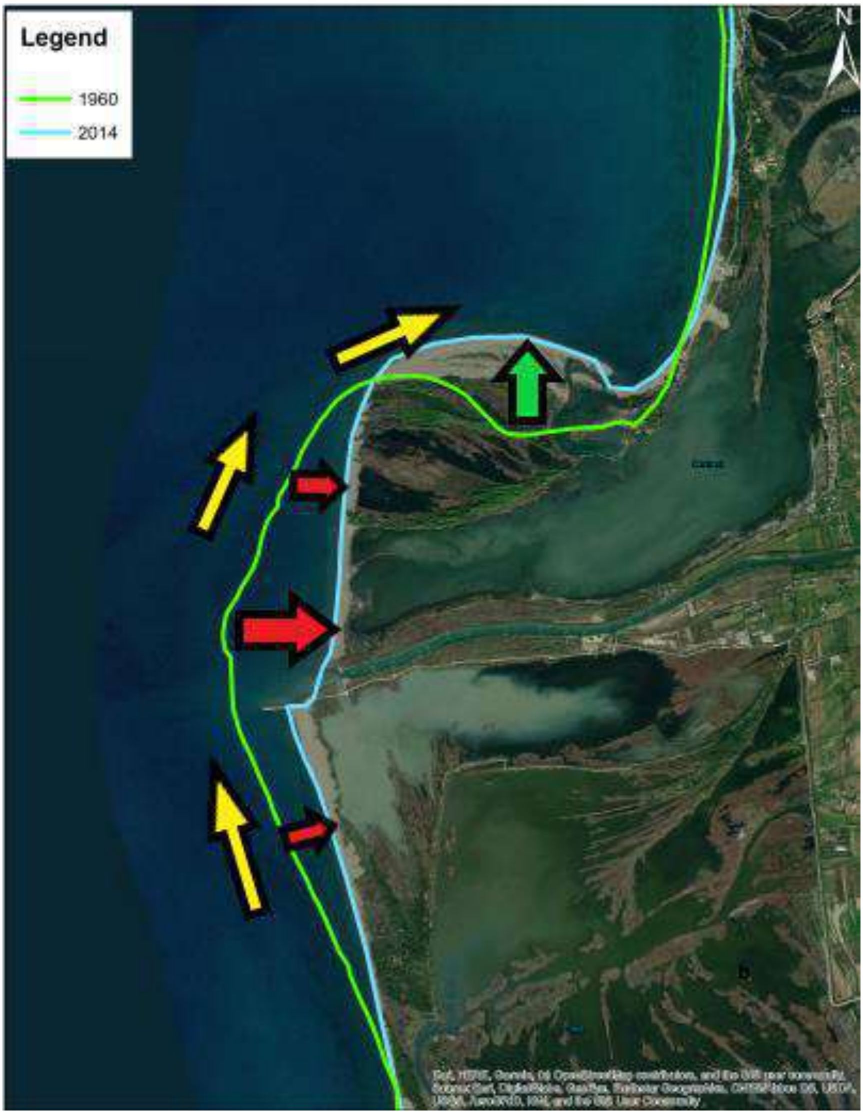


Fig.3: Coastline alteration in the Buna Delta (left) and Drin-Lezha Delta (right).

Coastal habitats have been subject to erosion and alteration since the construction of the first hydropower dams along the upstream of Drini River. Sand dunes are the most affected habitat type, having shrunken by about 63% across both Buna and Lezha deltas, because of the negative sedimentation budget. Coastal lagoons and estuars have also shrunken in size, with alluvial *forests with a noted increase in surface area in Buna, mostly due to them replacing other types of habitats. However, theDrin-Lezha alluvial forests have a decrease in surface area.*

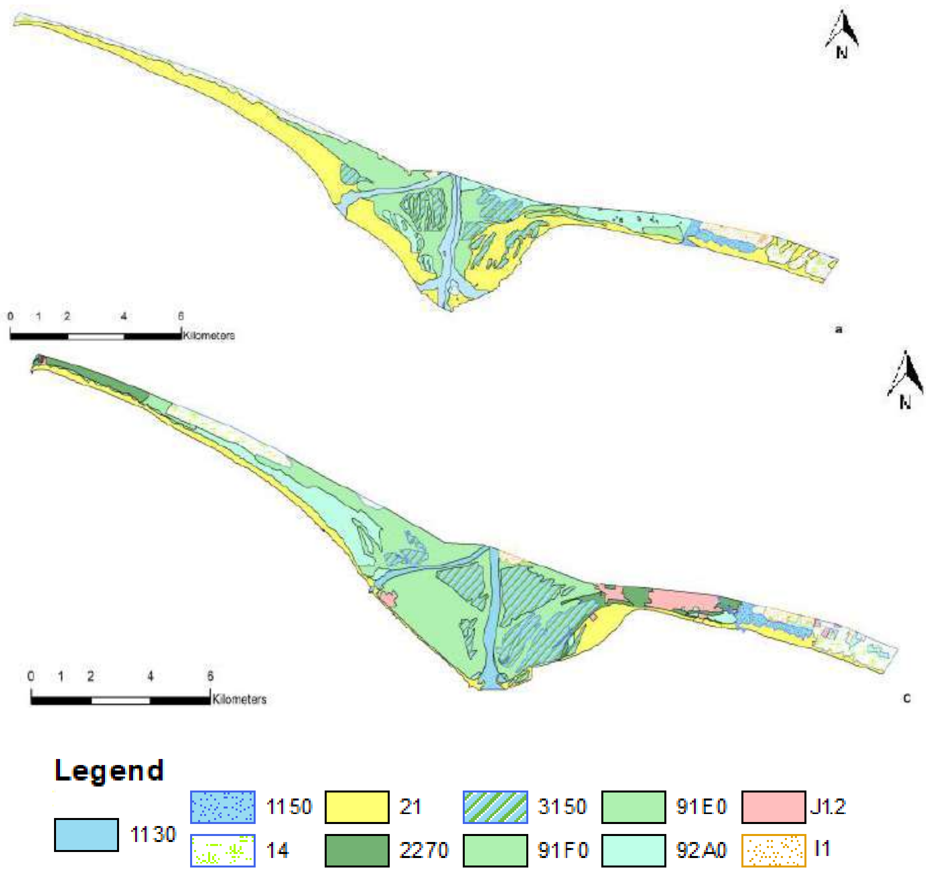


Fig.4: The habitat map of Buna Delta of 1960 (a) and 2014 (c).
Codes refer to habitats as follows: **1130**- Estuaries, **1150**- Coastal lagoons **14**- Mediterranean Salt Marshes, **21**- Sand Dunes, **2270**- Wooded dunes with Pinuspinea, **3150**- Natural eutrophic lakes, **91F0**- Riparian mixed forests of *Quercusrobur*, *Ulmuslaevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenionminoris*), **91E0**- Alluvial forests with *Alnusglutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnionincanae, Salicionalbae*), **92A0**- *Salix alba* and *Populus alba* galleries, **J1.2**- Residential buildings of villages and urban peripheries, **I1**- Arable land and market gardens

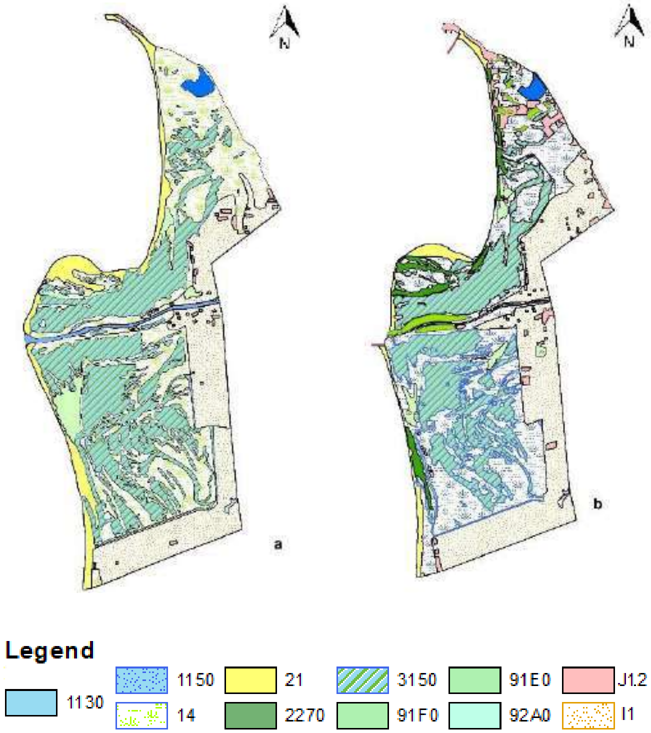


Fig.5: Drini-LezhaDelta habitat map of 1960(a) and 2013(b).
Codes refer to habitats as follows: **1130**- Estuaries, **1150**- Coastal lagoons **14**- Mediterranean Salt Marshes, **21**- Sand Dunes, **2270**- Wooded dunes with Pinuspinea, **3150**- Natural eutrophic lakes, **91F0**- Riparian mixed forests of *Quercusrobur*, *Ulmuslaevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenionminoris*), **91E0**- Alluvial forests with *Alnusglutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnionincanae, Salicionalbae*), **92A0**- *Salix alba* and *Populus alba* galleries, **J1.2**- Residential buildings of villages and urban peripheries, **I1**- Arable land and market gardens.

In 1960 human settlements took up an average of 7.07ha (0.1% of the total area in the study zones), growing over 200 ha in 2014 and continuing on an exponential upward trend. This is an added pressure to natural coastal habitats which are already being negatively impacted by coastal erosion.

In both deltas, the riverbank noted a decrease in average width since 1971, after the construction of “Vau i Dejes” HP dam, as shown in Table 1. This increased the risk and incidence of floods, adding severe economic setbacks to the list of negative impacts of hydropower plants have caused.

Table 1. Riverbank width for both deltas in the river section leading to the delta mouth

Delta / Average riverbank width	1960	2014
Buna (West Branch)	190.56m	154.63m
Buna (East Branch)	505.82m	348.19m
Drin- Lezha	75.15m	40.36m

Both Drini-Lezha and Drini-Buna deltas are currently found in a state of degradation. Their once characteristic shovel-shaped deltas have been gradually getting flatter under the effect of intensive coastal erosion, with a negative sediment budget and an entirely halted progradation. Comparing the rate of progradation of both deltas before and after the construction of HPPs along upstream Drini river in 1971, it is evident there is an undeniable correlation between these events. The Buna delta front has receded by ca. 750m, an annual average of 13m since 1960. Likewise, in Drin-Lezha delta front has receded by ca. 660m, an annual average of 12m since 1960. Sand dunes, coastal lagoons, alluvial forests are among the most affected habitats in both deltas, being subject to coastal erosion, natural succession, eutrophication, as well as urbanization and tourism development. Many coastal habitats have been replaced and lost, or altered to accommodate the ever-increasing human presence in the areas.

Not only there have been substantial losses in habitats and alterations of the coastal ecosystem, but also the resilience to climate change and carrying capacity of the ecosystem as a whole has been reduced as proved by the drastic decline of colonial water bird populations over the years in Kune-Vaini lagoon complex (from a colony counting 2000-2500 breeding pairs in the 1950s, to a colony counting only 420-600 breeding pairs in 2020) (Selgjekaj 2020; Selgjekaj and Bego 2021).

4. SUGGESTIONS AND RECOMMENDATIONS

The information here provided is a means to address the conservation of other parts of the Albania's coast that are expected to be impacted by other HP dams in a near future in other rivers' watersheds. Conservation of the coastal wetlands and their biodiversity is of an exeptional ecological, social and economic importance. Albania is committed to protecting and henancing the conservation of the coastal wetlands and their related biodiversity due to the various international conventions that have been signed or ratified. *Acknowledging the adverse impacts of extensive and unsustainable* *hydropower project development and the lessons learnt from the Drini River case are critical.*

Delta degradation following hydropower plant construction upstream is inevitable. Although remediation is possible and necessary for Drini River, it is not cost effective at this stage, because constant effortsare required toemprove the sedimentation load downstream. Consequently, holistic approach adopting sustainable development standards, exploring alternative renewable energy sources to avoid the same mistakes with other rivers in Albania, specifically with Vjosa River would be vital.

REFERENCES:

Bego F, Mullaj A, Kashta L, ZotajA. 2012. The status of the habitats of European conservation interest along the Adriatic coast of Albania. *International Journal of Ecosystems and Ecology Science* (IJEES) 01/2013; **3/2:**203-210.

Boçi E. 1994. Evoluzione e problematiche ambientali del litorale Albanese. *BolletinodellaSocietàGeologicaItaliana,***113:** 7-14.

Collier M, Webb RH, Schmidt JC. 1996. *Dams and Rivers - A primer on the downstream effects of dams.*US. Geological Survey Circular 1126. Tucson, Arizona.

Dhora Dh. 2017. Karakteristikat e Kompleksit Hidrologjik të lumenjve Drini dhe Buna, si dhe liqeneve të Shkodrës, Ohrit, Prespës së Madhe dhe të Vogël, Fiorentia, 64 pp.

Faloutsos D, Markovic M, Shipman B. (Eds.) (2015): Integrated Resources Management Plan (IRMP) for Buna/Bojana Area, 225 pp.

Fouache É, Gruda G, Mucaj S, Nikolli P. 2001. Recent geomorphological evolution of the deltas of the Rivers Seman and Vjosa, Albania. *Earth Surface Processes and Landforms*, **26 (7):** 793-802.

Frashëri A, Pano N. 2003. Impact of the climate change on Adriatic Sea hydrology. Published by Elsevier, Amsterdam.

Gjiknuri L. 1995. The Albanian sea-coast: problems and perspectives. In: BRIAND, F. (ed.) – Les merstributaires de Méditerranée – Mediterranean tributary seas. Bulletin de I'InstitutOcéanographique, Monaco, Numérospécial 15, CIESM Science Series n°1. Monaco: 187-201.

Kabo, M. (ed.) (1990-91): Gjeografia Fizike e Shqipërisë (Physical Geography of Albania). Vols. I & II. Akademia e Shkencave e RPS të Shqipërisë, The Albanian Academy of Sciences, Qendra e Studimeve Gjeografike (Centre of Geographical Studies). Tirana. (in Albanian).

Kowalewski M, Avila-Serrano GE, Flessa KW, Goodfriend GA. 2000. Dead delta's former productivity: Two trillion shells at the mouth of the Colorado River. *Geology* **28(12):** 1059-1062.

Le Tissier, M. (eds) (2013): "Identification and Implementation of Adaptation Response Measures in the Drini – Mati River Deltas". Project Synthesis Report. GEF/UNDP.

Mathers S, Brew DS, Arthurton RS. 1999. Rapid Holocene evolution and neotectonics of the Albanian Adriatic coastline. *Journal of Coastal Research*, **15 (2):** 345-354.

Meçaj N. 2005. Protection of the littorals of the Kune – Vain Lagoons, by using ecotechniques to manage coastal erosion. In: Gutiérrez, F., Gutiérrez, M., Desir, G., Guerrero, J., Lucha, P., Cinta, M. & J. M. Garcia-Ruiz (eds.) – Sixth International Conference on Geomorphology, Zaragoza, September 7-11, 2005. Abstracts vol.: **256**.

Milliman JD, Syvitski JPM. 1992. Geomorphic/tectonic control of sediment discharge to the oceans: The importance of small mountainous rivers. *The Journal of Geology*, **100 (5):** 525-544.

Milliman JD, Meade RH. 1983. World-wide delivery of river sediment to the oceans. *The Journal of Geology*, **91 (1):** 1-21.

Milliman JD. 1997. Blessed dams or damned dams? *Nature* **386**: 325-327.

Pano N. 1992. Dinamica del litorale albanese (sintesi delle conoscenze). Proceedings of the 10th A.1.0.L. Meeting, G. Lang Publishers, Genova, Italy: 3-18.

Pano N, Avdyli B.2009. A method to estimate Buna River discharge, Albania. Hydrology Days 2009: 66-72.

Pettorelli N., Laurance B., O'Brien T., Wegmann M., Harini N., Turner W. (2014a): Satellite remote sensing for applied ecologists: opportunities and challenges. *Journal of Applied Ecology*. **51**:839–848.

Pettorelli N, Safi K. Turner W. 2014b. Satellite remotesensing, biodiversity research and conservation of the future. *Philosophical Transactions Royal Society*. **B 369**:20130190.

Rosenberg DM, McCully P, Pringle CM. 2000. Global-scale environmental effects of hydrological alterations: Introduction. *Bioscience* **50(9):** 746-751.

Sahagian D. 2000. Global physical effects of anthropogenic hydrological alterations: sea level and water redistribution. *Global and Planetary Change* **25(1-2):** 39-48.

Selgjekaj L. 2020. Vlerësimi i suksesit të riprodhimit të shpendëve ujorë në kompleksin lagunor të Kune-Vainit, M.Sc. thesis, University of Tirana, Department of Biology.

Selgjekaj L, Bego F. 2021. On the colonial breeding waterbirds in the lagoonary complex of Kune-Vaini, WEPSD-2021.

Simeoni U, Pano N, Ciavola P. 1997. The coastline of Albania: morphology, evolution and coastal management issues. In: Briand, F. (ed.) – Transformations and evolution of the Mediterranean coastline. Bulletin de I'Institut océanographique, Spécial No: 18. CIESM Science Series n°3. Monaco: 151-168

Uncu L. 2011. Holocene landscape changes of the Lezha region-A contribution to the palaeo-geographies of coastal Albania and the geo-archaeology of ancient Lissos. PhD thesis. 347 pp.