Journal of Materials and Environmental Sciences
ISSN: 2028-2508
CODEN: JMESCN

J. Mater. Environ. Sci., 2020, Volume 11, Issue 3, Page 486-498

http://www.jmaterenvironsci.com

Impact of hydrodynamic forcings on the morphodynamics of Idenau beach, Western Cameroon coast

A. Kouekam Kengap[1], F. Togue Kamga [2*], P.G. Fowe Kwetche[2], J. R. Ngueguim[3], W. Enow Atem[2], L. J. Mbang Essome[2], I. L. Ntangyong [2]

[1] Specialized Research Station for fisheries and Oceanography PMB 77 Limbe-Cameroon
[2] Institute of Fisheries and Aquatic Sciences PO Box 7236 Douala-Cameroon
[3] Agricultural Research for Development Institute (liaison office)

Received 03 Nov 2019,
Revised 15 Feb 2020,
Accepted 17 Feb 2020

Keywords
- ✓ beach,
- ✓ hydrodynamic,
- ✓ morphodynamic,
- ✓ erosive,
- ✓ accretion

kamgafulbert@yahoo.fr ;
Phone: +237690980854;
Fax: +21329824945

Abstract
Beaches are characterized by complex spatial and temporal patterns of erosion and accretion subjected to significant wave and tide influence. This work deals with the characterization of the impacts of natural factors on the morphodynamic evolution of Idenau beach, western Cameroon coast. The method used was the collection of data through topographic surveys of the selected site station (Idenau) using a total station and a GPS. The data of the various hydrodynamic forcings collected on the websites have been validated using measurements made in situ with the tide scale. The particle size analysis of the sediment samples taken was carried out in the laboratory. The results obtained show that generally during the study period, the Idenau beach with a slope of 24.25% underwent sedimentary accretion with a rate varying between +0.04 m/day and +0.12 m/day. The particle size analyzes coupled with the hydrodynamic data reveal that Idenau beach is an intermediate beach (Ω = 1.16) and is weakly influenced by the tide (RTR = 1.88). This work reveals that the hydrodynamic forcings strongly affect the morphodynamic evolution of the beaches. This paper highlights the importance of identifying vulnerable area of a beach so that suitable measures can be engaged to prevent coastal erosion and loss of land.

1. Introduction
The study of morphodynamic beach evolution consists in linking hydrodynamic forcings, sedimentary transport processes and morphological development at all timescales [1]. This approach involves defining the properties of a morphodynamic system, as well as examining the spatio-temporal scales at which the evolution of the coastal system can be apprehended [2].
Coastal erosion is one of the main environmental problems facing coastal areas [3]. Since at least 60% of sandy beaches across the globe are currently being eroded [4], the erosion of coastal areas is certainly a topic of great concern worldwide.
Coastal environments are located on the border of the continent and the ocean between domains that all opposes, they form a particular interface that is still poorly known at present. According to Mrini *et al.*, (2012) [5], the type and mobility of beaches are a function of their curvature and distance from headlands, exposure to waves, grain size and sediment supply. Thus, the dynamic processes, the

constituents of the environment and their relations have never been fully analyzed. Anthony *et al.*, (2017) [6] showed that beach changing morphodynamics are related to complex interactions involving river water and sediment discharge, waves and wave-generated longshore currents, tidal currents, and shoreline orientation. According to Hoefel and Elgar, (2003) [7], high energy wave conditions results in beach erosion. In contrast, Eichentopf *et al.*, 2018 [8] (among others) associated mild energy wave conditions with sediment accretion. In fact, it seems that the study of the littoral is an inexhaustible subject because the coasts are diversified around the planet and variable in time [9]. Three indicators namely the shoreline location, sediment volumes, and the beach state area used for defining beach recovery [10].

According to Gensac *et al*., 2016 [11], sediments transport under the influence of continental and oceanic forcing drives the geomorphologic change along the coast. However, the evolution of the morphology of the beaches there remains very little known face ocean forcings. The Cameroonian coastline, located in the Gulf of Guinea, experiences coastal erosion, more specifically the study at different time scales of the response of the beaches of the west coast of Cameroon (Idenau) is therefore a scientific issue for the understanding of the evolution of the Cameroonian coastline. Given this context of environmental crisis, it is important to conduct a thorough study on the morphodynamic characterization, as well as the evolution of this coastal area particularly on the West coast of Cameroon. In addition, it is clear that a better knowledge of the coastal environment should allow for a more harmonious, more sustainable and safer development of human activities in these border areas [9]. Moreover, coastal erosion management should be properly structured and organized in such a way that every stakeholder is considered during the early stages of the planning process [12]. According to Reed *et al*., 2009 [13], it is fundamental that more active and effective stakeholders become concerned at the early stages, especially when making management decisions or proposing solutions. Therefore, the general objective of this study is to make a contribution to the characterization of the morphodynamic evolution of the beaches of the west coast of Cameroon in response to hydrodynamic forcings. More specifically, it will be necessary to characterize the hydrodynamic forcings (wave, energy of wave, tide and wind), to establish the morphological profiles of the Idenau beach and to establish a relationship between the morphological profile obtained and the hydrodynamic forcings characterized.

2. Material and Methods

The study site Idenau is located at the foot of the active volcano Mount Cameroon between latitudes 4° 13’20.9891’’ and 4°13’22.1952’’ North and longitudes 8°58'56.1792" and 8°58'54.9192 " East. The site is, therefore, covered with basaltic flows from its different eruptions. The minerals in its rocks are hydrolysed by warm and abundant rainwater, defining a ferralitic type soil [14]. The climate prevailing in the study area is tropical coastal with two seasons: a long rainy season from February to November with July the wettest month (720 mm) and a short dry season from December to January with March the hottest month (26.4 °C average temperature). (Source: www.climate-data.org).

2.2. Material

The main material used in this work is:

- A Leica MTS-602 branded total station, with a range of 300m and accuracy of ± 2mm for surveying;
- A GARMIN mobile GPS of the series MONATANA 650t for the acquisition of geographical coordinates of the various raised points;
- 12 plastic bottles of 1 liter for the sampling of sand samples on the beach;

- The tide scale of 4 m for validating the data of waves and tides collected every three hours from the websites www.surf-forecast.com/breaks/Seme-Beach and [www.mareespeche.com/af/cameroon/ bekumu](www.mareespeche.com/af/cameroon/bekumu) respectively.

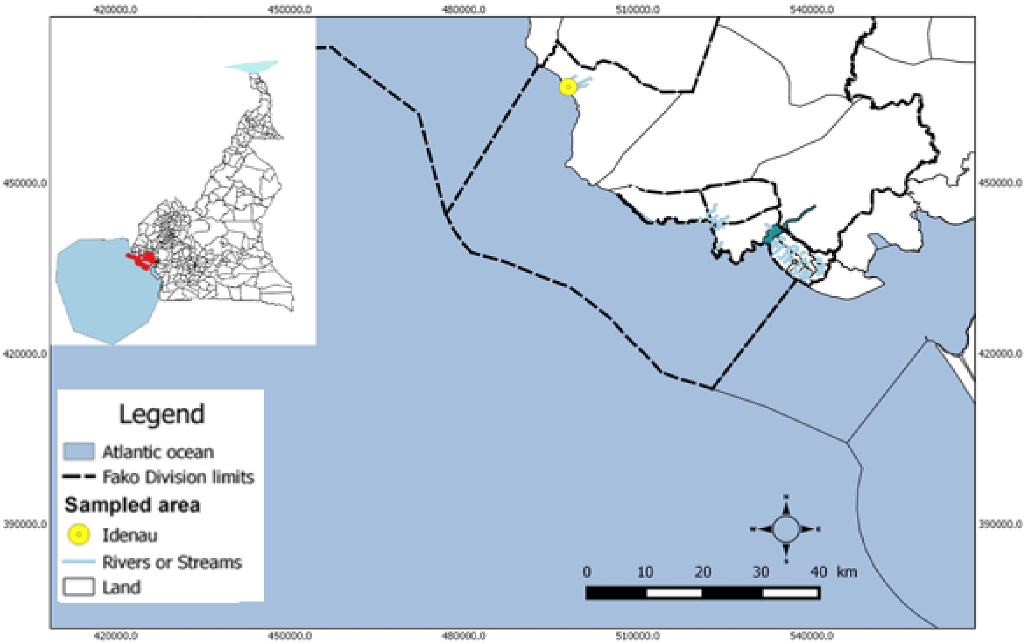

Figure 1: Location map of Idenau area

2.3. Methodology

2.3.1 Topographic survey

A five day successive campaign was carried out to carry out the topographical surveys during the period from 10th May to 14th May, 2018 during the low tide periods on the beach which is not subjected to human pressure and thus, ideal to study its natural morphodynamic evolutions with the help of a total station and a portable GPS. For this purpose, before starting the field surveys, a fixed point representing the reference was chosen. This point whose coordinates were taken, served as a reference for each descent on the field. The total station is always placed above the reference point (where the reference point was marked). The height of the total station is measured from this point to create a relative referencing system. The operation required the presence of three people in the field: a reader placed at the reference point with the total station, an operator holding both the sight and the GPS placed at the place where the surveys were carried out and a third person recording the acquired data. The operator, equipped with a portable GPS and a sighting device, walked along the beach. Every four meters, the operator surveyed and took coordinates of the survey point simultaneously. Thus, a rectangular figure of 100 m long and 25 m of width was realized. Within this figure, topographic surveys of 100 points were made by making small internal squares of 16 m² surface in the direction of the North.

2.3.2 Particle analysis

Sampling was conducted along four radials lines perpendicular to the shoreline. For each radial, three samples were taken respectively at the three geomorphological units of the beach from the top of the beach to the bottom of the beach (top of the beach, foreshore and bottom of beach), or in total 12 samples taken. The samples taken were subjected to various treatments in the geotechnical laboratory of the Higher National School Polytechnic of Yaounde. They were placed on metal plates, dried in an oven for

24 hours at 105°C, 1000 g were taken from each of the samples thus dried, to sieve along a series of sieves so the stitches are spread out between 0.1 and 5 mm. The different refusals and bystanders were weighed and recorded in the book laboratory.

2.3.3 Typology of beaches

The physical behavior of a beach can be characterized according to the degree of reflection or dissipation of wave energy. To evaluate these characteristics, we used the Dean parameter Ω with has traditionally been used to determine the overall beach tendency (erosion or accretion) for a given wave climate [15] (Equation 1) and the tidal parameter given by masselink et al., (1993) [21] (Equation 2):

$$\Omega = H_b/(Tw_s) \quad (1)$$

$$RTR = TR/H_b \quad (2)$$

where TR is the mean tidal range, T peak period, H_b (breaking wave height) estimated using the empirical formula developed by Komar (1974) [16] expressed as:

$$H_b = 0.39g^{1/5}(Tp.Hs)^{2/5} \quad (3)$$

where Hs and Tp are respectively the significant wave height and peak period

w_s is evaluated using the formula of Cheng (1997) [17]. It is expressed by:

$$w_s=\frac{\upsilon}{d}\ [(25 + 1{,}2d*^2)^{0.5}-5]^{3/2} \quad (4)$$

where d* is the dimensionless sediment diameter expressed by

$$d^* = [((s-1)\ g) / \upsilon^2)]^{(1/3)}.\ d$$

Where $s = \rho_s/\rho$, υ: kinematic velocity of water (10^{-6} m/s), d: sediment size (D_{50}, in m), ρ_s: sediment density (2650 kg/m^3) and ρ: density of seawater (1025 kg/m^3), g = 9.81 m / s^2.

3. Results and discussion

The results presented in the figures below show the hydrodynamic forcings responsible for the different sedimentary variations and associated morphological evolution of the beach of Idenau from 10th May to 14th May.

3.1. Characterization of the type of Idenau beach

The parameters measured or estimated, and used for the calculation of the parameter of Dean [15], are recorded in the table below. The range is said to be dissipative when Ω> 6, reflexive if Ω <1 and intermediate when 1 <Ω <6 [1]. The results are shown in the table 1 below:

Table 1: Measured and estimated data used in calculating Dean's Parameter

Hs average (m)	$H_{s,b}$ average (m)	Average tidal range (m)	D_{50} average (mm)	W_s (m/s)	Average tidal parameter RTR	Wave period T(s)	Dean parameter Ω
0.27	0.93	1.75	0.55	0.065	1.88	12.29	1.16

In order to characterize the beach according to the Dean parameter and the tidal parameter, we note from Table 4 that Ω is between one and six which means that Idenau beach has an intermediate behavior indicating that in Idenau site, the wave energy is both absorbed and reflected. As for the average tidal parameter (RTR = 1.88), it is greater than 1 indicating that hydrodynamism is dominated by the tide. Available long term measurements of beach profiles and incident waves has been used by Karunarathna, *et al*., (2016) [18] to analyze, compares and contrasts cross-shore morphodynamic behavior of four diverse beaches (Narrabeen Beach, New South Wales, Australia; Milford-on-Sea Beach, Christchurch Bay, UK; Hasaki Coast, Ibaraki Prefecture, Japan; and Joetsu-Ogata Coast, Niigata Prefecture, Japan) that have very different regional settings, sediment characteristics and wave climates. The time-averaged profile at all four sites fall into either reflective, intermediate or dissipative states described by Short *et al.*, (2006) [19].

3.2 Characterization of general hydrodynamic forcings

The morphodynamics of coastal and estuarine areas are characterized by the flow conditions. The response of a beach is function of different possible combinations of hydrodynamic conditions (tides, waves, oceanic currents). Any alteration on the average flow conditions caused by human interventions (i.e. bridge, port constructions or dredging interventions), can be regard as a potential driver producing morphodynamic changes. Wave, wind and tide data for April and May have been analyzed and synthesized in this section to characterize the hydrodynamic parameters whose beach were exposed during the study period.

3.2.1 Wave conditions

Direction

During the study period (Figure 2), there were five types of wave depending on the direction: the dominant south (S) direction with 62.91 %, the South-South-West (SSW) direction with 25.82%, then South West (SW) with 7.95%, West (W) with 1.99% and West-Southwest (WSW) with 1.32%.

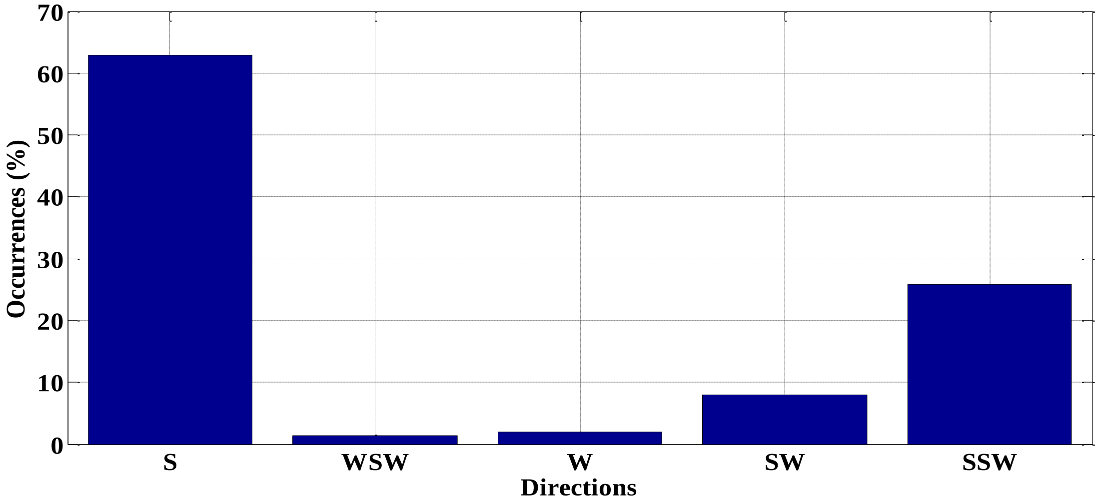

Figure 2: Dominant wave directions in April and May 2018

Significant wave height (Hs), Peak period and Significant wave energy.

The maximum significant wave height is 0.7 m and minimum is 0.1 m, with an average value of 0.27 m (Figure 3) showing that the sea is relatively calm in most cases during the period of the study according to the Douglas classification. Peak periods range from 4 s to 18 s with an average value of 12.29 s (Figure 4).

The significant wave energy (Figure 5) at breaking is given by the equation:

$E = \frac{1}{16}\rho g(H_{s,b})^2$ where $\rho =$ density of seawater (1025 kg/m^3), g = 9.81 m / s^2 and $H_{s,b}$= significant breaking wave height and calculated following Komar (1974)[16]: $H_{s,b} = 0.39 g^{1/5}(Tp.Hs)^{2/5}$

The results show that the maximum significant wave energy at breaking is 1252 N/m and minimum is 214.48 N/m, with an average value of 566.11 N/m

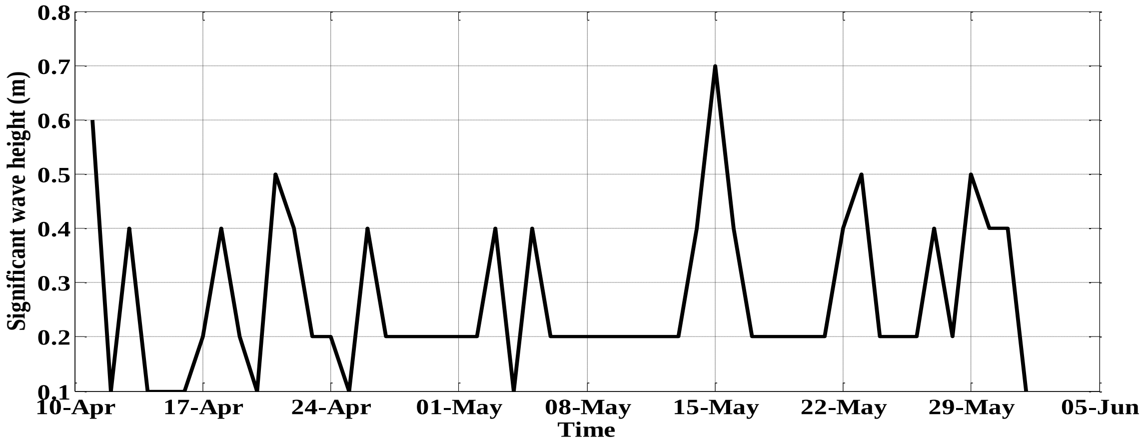

Figure 3: Significant wave height in April and May 2018.

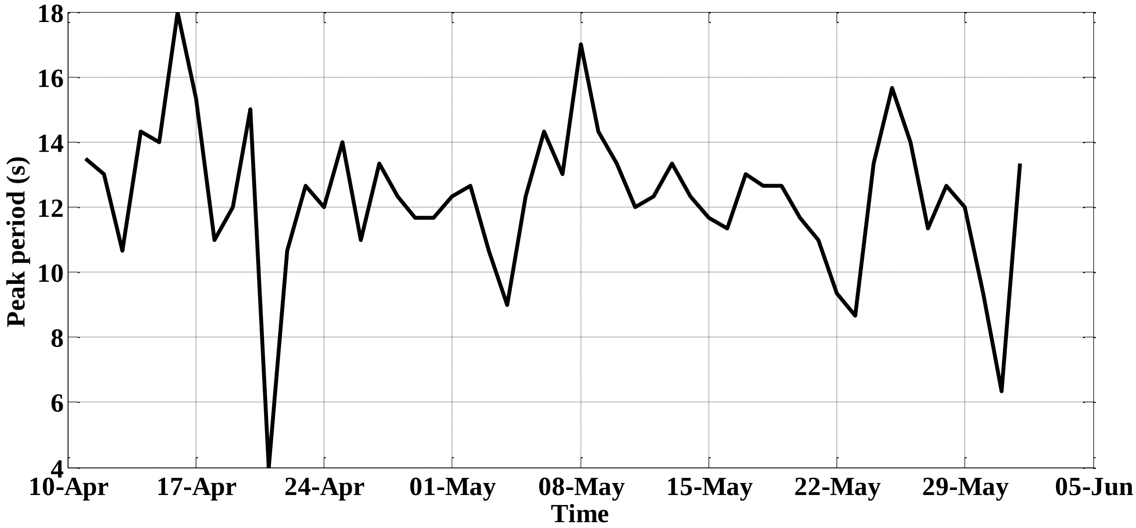

Figure 4: Peak period in April and May 2018

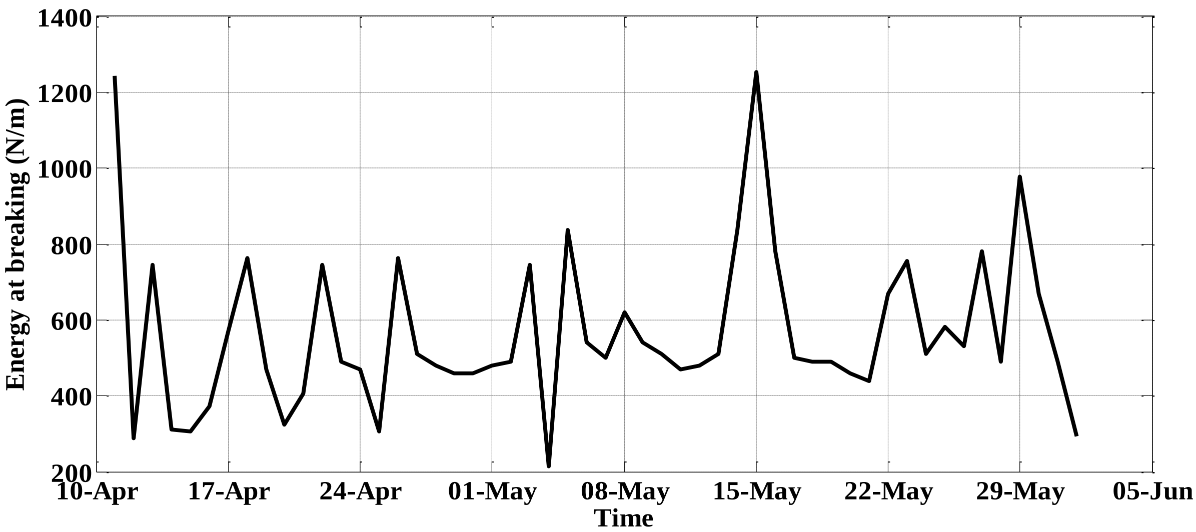

Figure 5: Significant wave energy at breaking estimated in April and May 2018

3.2.2 Tide conditions

In Figure 6, the maximum tidal range is 2.2 m and minimum is 1.25 m recorded during the two months of data collection with an average value of 1.75 m less than 2 m characterizing a micro-tidal range according to Stépanian (2002) [2].

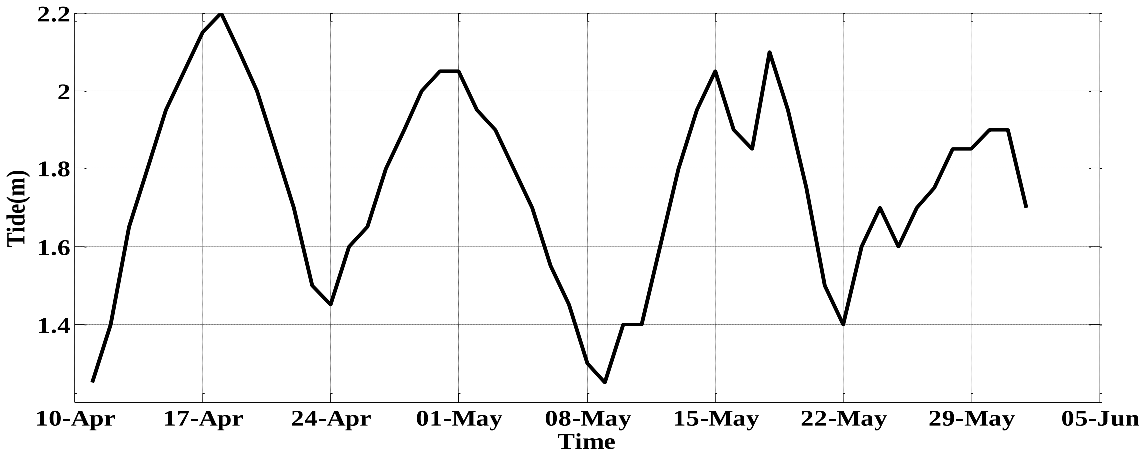

Figure 6: Tidal range in April and May 2018.

3.2.3 Wind conditions

Wind direction and speed

Regarding the wind data in Figure 7, nine directions were recorded: the west direction (W) dominant with 37.74%, the direction West-South-West (WSW) secondary with 21.38%, then follows the direction West-North-West (WNW) with 16.98%, then South-West (SW) with 8.8%, then South-South-East (SSE) and South-South-West (SSW) with 5.66%, finally South-East (SE) , East (E), South (S) with 1.26%. In Figure 8, the maximum wind speed is 18.33 km/h and the minimum is 5 km/h all recorded during the month of May. The average value of the measured wind speed is 9.66 km/h, which characterizes the conditions of weak wave, as the ripples on the sea are observed according to the Beaufort classification.

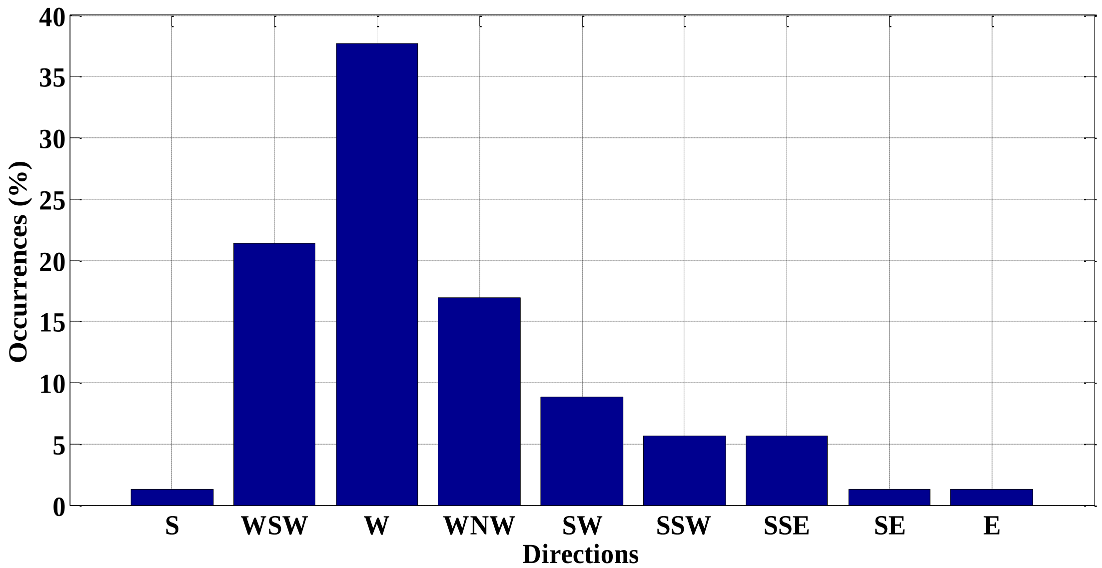

Figure 7: Dominant wind direction in April and May 2018

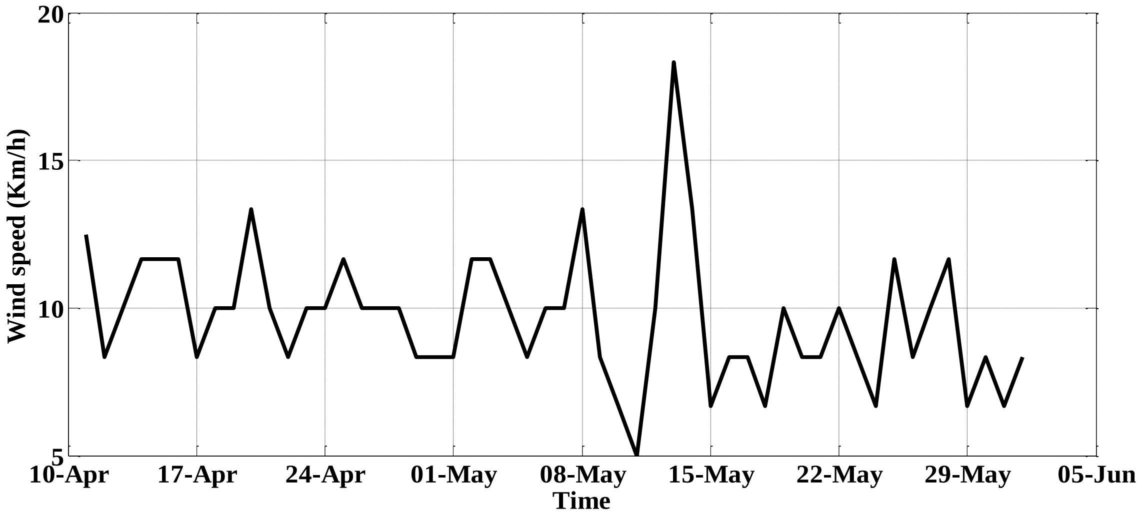

Figure 8: Wind speed in April and May 2018

In general, the hydrodynamic forcings show that Idenau beach is exposed to a micro-tidal environment with a tidal range of less than 2m and implies that the tidal currents are generally low. The sea is relatively calm with a mean of significant wave height (Hs) between 0.1 m and 0.5 m according to the Douglas classification and a weak dynamism relative to an average wind speed of between 6-11km/h according to Beaufort classification. Idenau beach is thus exposed by the hydrodynamic conditions generally low during the study period. However, Karunarathna, *et al.*, (2016) [18] showed that irrespective of the differences in mean beach slope and sediment size, the profile change at Narrabeen Beach and Hasaki Coast is governed by the movement of inter-tidal/sub-tidal bar.

3.3 Short-term morphodynamic evolution

The short-term approach aims to understanding beach morphological evolution during high frequency topography measurement. The goal is to understand the processes responsible for erosion or beach accretion and to explain their mobility and destruction at this time scale. This requires knowledge of the morphological response of beach to clearly identify the effect of variations of hydrodynamic forcings.

3.3.1 General evolution of the cross-shore profiles of the Idenau beach

The cross-shore profiles of Idenau beach make it possible to follow the evolution of each parts of the beach. This cross-shore profile is obtained by making average of all altitude point surveyed in all cross-shore point of our sample zone. The overall slope of the beach is about 24.25% (Figure 9). From 10th May to 11th May, it is noticed an erosive phase that begins at the level of the top of beach intensifies at the level of the foreshore and persists until the bottom of beach. It is observed a stability of the top of beach, an erosive phase is initiated and persists until the bottom of beach on 11th May to 12th May. From 12th May to 13th May, an erosive phase begins at the top of the beach and ends on the foreshore, the bottom of the beach is relatively stable. It is observed the general accretion of the beach which starts at the bottom of beach, then intensifies at the level of the foreshore and is very strong on the high beach on 13th May to 14th May.

In Figure 9, with regard to the evolutionary dynamics of morphologies, the studied site (Idenau) behave in the same way in general on a short time scale, we can observe a strong daily morphological variability of Idenau beach. Thus, morphological differences observed testify the variation of the sedimentary volume for each campaign carried out.

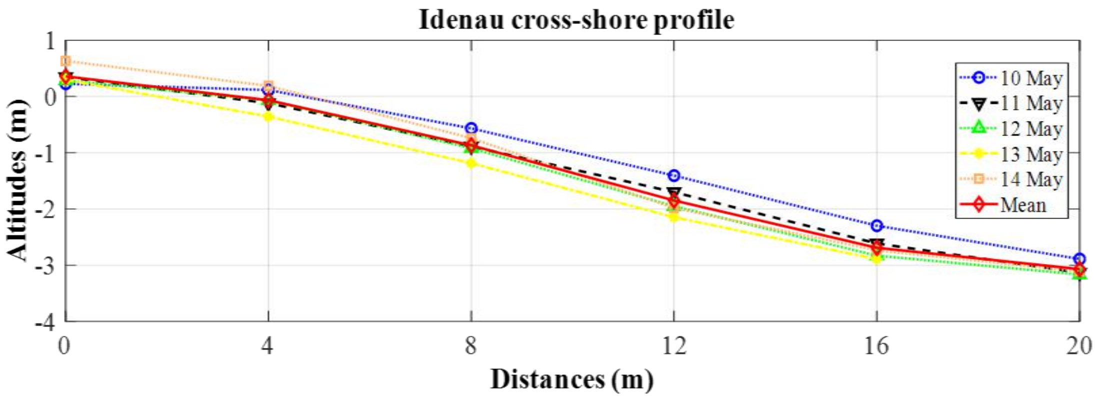

Figure 9: Evolution of topographic profiles of Idenau beach

3.3.2 Evaluation of sedimentary volume in the sample zone of the studied site (Idenau)

The morphological variations of Idenau beach observed below, lead us to calculate the volumes of sand contained in the beach at each measurement period. The different sediment volume values were obtained using the MATLAB 2013a software. Table 2 summarizes the sediment volumes obtained in all the sample zone of our site studied during the campaigns from 10th May to 14th May, 2018.

Table 2: Summary of sedimentary volumes obtained in the sample zone of Idenau site

Date of the profile measurement	Sedimentary volumes (m^3)
10/05/2018	2176
11/05/2018	3377.2
12/05/2018	1832.3
13/05/2018	5192.8
14/05/2018	4552.5

Table 2 indicate the sedimentary volume in the whole area of our sample zone (100m x 25m). The variations in sedimentary volume in the Idenau site show that between 10th May and 11th May, the beach undergoes a slight deposit of sediment. But, the day of 12th May is marked by a departure of sand on the beach. The day of 13th May is animated by an accentuated accretion of sediment on the beach, to fall to a slight erosive phase on 14th May at the end of the campaign in this site. Tidal and wind forcing of the water column are responsible for the important beach morphological changes, and especially the foredune erosion (Anthony *et al*., 2017) [6].

3.3.3 Evaluation of the Sediment Balance in the sample zone of the studied site

The sediment balance between two consecutive days was calculated to assess the dynamics of the beach during the campaign. The overall sediment balance is thus obtained by making the difference between the final volume obtained on the last day of the campaign and the reference volume obtained first day of campaign $V = V_{final} - V_{initial}$. Table 3 summarizes the sediment balances obtained at the Idenau site during the campaigns running from 10th May to 14th May, 2018. The overall sedimentary balance calculated in the sample zone of Idenau site is positive and equal to 2376.5 m^3. This means that Idenau beach has undergone a sedimentary accretion in the space of five days. Sticking only to the overall sediment balance does not allow us to really investigate the dynamics of the beach on each morphological unit of the beach. Thus, global disturbance maps between the first day of the campaign and the last day were established to better understand the morphological variability of Idenau beach.

Table 3: Summary of the daily sediment balances of the sample zone of Idenau site

Study period	Sedimentary balance sheet (m^3)	Evolutionary trend of the beach
10 to 11/05/2018	1201.2	Accretion
11 to 12/05/2018	-1544.9	Erosion
12 to 13/05/2018	3360.5	Accretion
13 to 14/05/2018	-640.3	Erosion
10 to 14/05/2018 (global balance sheet)	2376.5	Accretion

3.3.4 Evaluation of the global disturbances in the sample zone of the site studied.

The red areas represent the areas of sediment deposition on the beach, the areas in blue represent areas of sediment deficit and the intermediate zone (greenish) represents stability. The longshore and the cross-shore (distance in meter) represent the length parallel to the beach and the width perpendicular to the beach from the top of the beach to the sea. The color differences on the scale bar represent variations in sediment levels over the change in elevation relative to the reference. In this figure, the top of the beach is located at the right on the longshore at the top (cross-shore side) and the bottom of the beach is located at the left side, which is in permanence in contact with the ocean. By observing the global disturbance map of the Idenau site (Figure 10), we realize that the top of the beach during the campaign has mostly undergone an accretion phenomenon with a change in elevation varying between +0.2 m and + 0.6 m in five days, either the rate of the evolution varying between +0.04 m/day and +0.12 m/day. The foreshore has both stable and eroding areas with a change in elevation of -0.2 m to -0.6 m in five days, either the rate of the evolution varying between -0.04 m/day and -0.12 m/day while at the bottom of the beach it is mostly stable with some sides marked by erosion.

3.4 Characterization of hydrodynamic forcings during the studied period

The hydrodynamic forcings of the study period (10^{th} May - 14^{th} May) are presented in Figure 11. This figure shows the daily average of hydrodynamic forcings recorded every three hours during the studied period. The significant wave height and wave energy are constant from 10^{th} to 12^{th} May and after 12^{th} May, the increase until the end of the measurement campaign. Concerning the tide, it increases throughout the measurement campaign and peak period increases from 10^{th} to 12^{th} May and after 12^{th} May, it decreases until the end of the campaign.

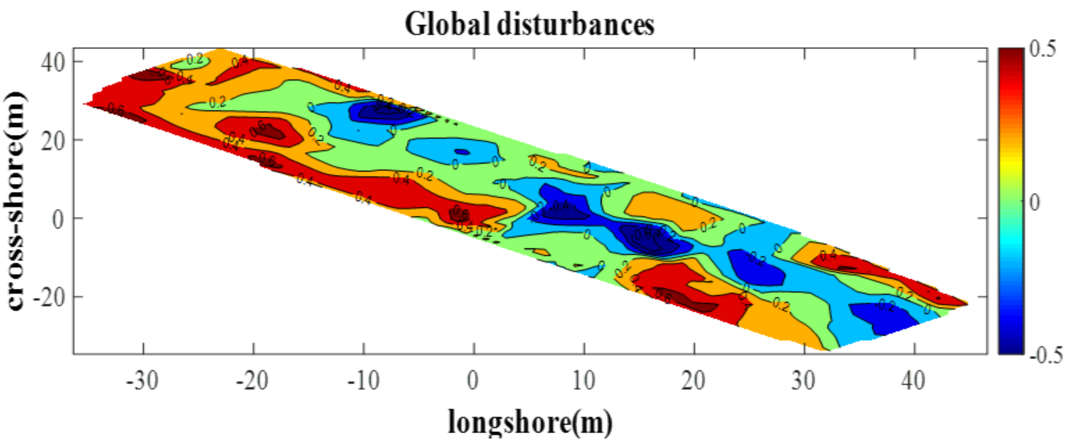

Figure 10: Global disturbance map of the Idenau site

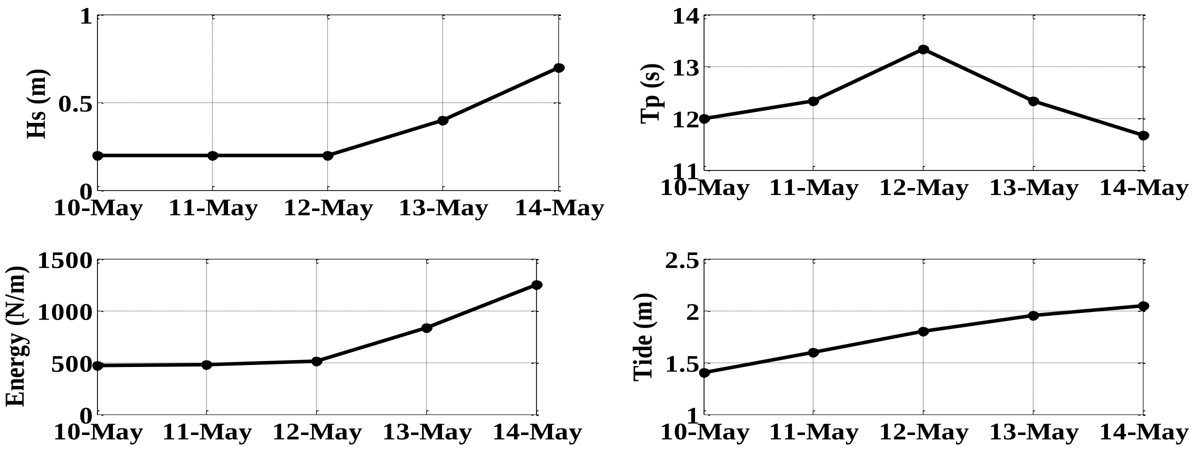

Figure 11: Hydrodynamic forcings during the study period (10th May to 14th May): Significant wave height (top of the left), Peak period (top of the right), Energy (bottom of the left) and Tidal (bottom of the right).

3.5 Relationship between morphological profile and hydrodynamic forcings

This section describe the existing relationships between the different hydrodynamic forcings of the study period (10th May – 14th May) and the variations of the sedimentary balance (Table 3). According to the figure 9, from 10th May to 11th May, an erosive phase begins at the level of the top of the beach, intensifies at the level of the foreshore and persists until the bottom of beach. The tidal range increases, the significant wave height and energy are constants and peak period increases. From 11th May to 12th May, a stability of the top of the beach, an erosive phase is initiated at the level of the foreshore and persists until the bottom of beach. The tidal range increases, the significant wave height and energy are constants and the peak period increases. From 12th May to 13th May, an erosive phase begins at the top of the beach and ends on the foreshore, the bottom of the beach is relatively stable. The tidal range increases, the significant wave height and energy increases, the peak period decrease. From 13th May to 14th May, the general accretion of the beach starts at the bottom of the beach, then intensifies at the foreshore and is very strong on the top of the beach. The tidal range increase weakly, the significant wave height and energy increases and peak period decreases.

In general, the accretion phases of the beach is accompanied by the tidal range who increases weakly, the significant wave height of the wave and the energy of the wave increase, while the peak period of the wave decrease. Erosion is accompanied by a growth of the tidal range, peak period of wave, while the significant wave height and energy are constants. These observations show that the morphodynamic adjustment time is variable depending on the intensity of the agitation and the previous morphodynamic phase (accretion or erosion phase). It also appears that it is the rapid change of agitation conditions is causing morphodynamic changes. This conclusion is identical to that found by Stepanian, (2002) [2] in his work on the morphodynamic evolution of a macrotidal beach bar (Omaha Beach, Normandy). Araffin *et al.*, (2018) [20] showed that artificial structures can also influence the wave regime, hydrodynamic circulation and sediment transport.

Conclusions and outlook

The study of the impact of hydrodynamic forcings on the morphodynamics of Idenau beach of the west coast of Cameroon was carried out in order to make a contribution to the characterization of the morphodynamic evolution of a beach of the west coast of Cameroon in response to forcings hydrodynamic. The morphological profiles of the beach were established, the hydrodynamic forcings (tide, significant wave height, peak period, wind and energy) were characterized. The main results obtained show that during the study period, Idenau beach underwent sedimentary accretion. The Dean parameter reveal that Idenau beach is intermediate (Ω =1.16), and weakly influenced by the tide. In perspective, it will be necessary to repeat these studies at medium and large time scales. This future work is needed to better understand and predict the evolution of the morphology of the beach studied and other beaches of the west coast of Cameroon.

Acknowledgements - The authors would like to thank the staff of the Specialized Research Station for fisheries and Oceanography at Limbe Cameroon for use of their facilities and logistical support in the field. Authors also thanks the anonymous reviewers whose comments have greatly improved this manuscript.

References

1. L. D. Wright & B. G. Thorm; Coastal depositional landforms: A morphodynamic approach. *Progress in Physical Geography,* 1(3), (1977) 412–459.
2. A. Stépanian; Evolution morphodynamique d'une plage à barres : Omaha beach (Normandie). Thèse de doctorat, Université de Caen, Basse-Normandie, (2002) 276 p.
3. A.C. Ibe, & L.F. Awosika; Sea level rise impact on African coastal zones. In: S.H. Omide and C. Juma (Editors), A change in the weather: African perspectives on climate change, African Centre for Technology Studies, Nairobi, Kenya, (1991)105-112.
4. R. Durgappa; Coastal protection works. In: Seventh International Conference of Coastal and Port Engineering in Developing Countries, Dubai, (2008)
5. A. El Mrini, M. Maanan, E. J. Anthony & M. Taaouati; An integrated approach to characterize the interaction between coastal morphodynamics, geomorphological setting and human interventions on the Mediterranean beaches of northwestern Morocco. *Applied Geography,* 35, (2012) 334-344
6. E. J. Anthony, P. Dussouillez, F. Dolique, M. Besset & M. Goichot; Morphodynamics of an eroding beach and foredune in the Mekong River delta: Implications for deltaic shoreline change. *Continental Shelf Research,* 147 (2017) 155-164
7. F. Hoefel & S. Elgar; Wave-induced sediment transport and sandbar migration. *Science* 299 (5614) (2003) 1885–1887. https://doi.org/10.1126/science.1081448
8. S. Eichentopf, I. Caceres & J. M. Alsina; Breaker bar morphodynamics under erosive and accretive wave conditions in large-scale experiments, Coastal Engineering, 138 (2018) 36–48
9. F. Desmazes ; Caractérisation des barres sableuses d'une plage de la côte aquitaine. Exemple de la plage du Truc Vert. Thèse de doctorat, Université Bordeaux 1, (2005) 292 p.
10. S. Eichentopf, H. Karunarathna & J.M. Alsina ; Morphodynamics of sandy beaches under the influence of storm sequences: Current research status and future needs. *Water Science and Engineering,* 12(3) (2019) 221-234. https://doi.org/10.1016/j.wse.2019.09.007
11. E. Gensac, J.-M. Martinez, V. Vantrepotte & E. J Anthony; Seasonal and inter-annual dynamics of suspended sediment at the mouth of the Amazon River: The role of continental and oceanic forcing, and implications for coastal geomorphology and mud bank formation. *Continental Shelf Research,* 118 (2016) 49–62. https://doi.org/10.1016/j.csr.2016.02.009

12. E. H. Ariffin, M. Sedrati, M. F. Akhir, N. R. Daud, R. Yaacob & M. L. Husain; Beach morphodynamics and evolution of monsoon-dominated coasts in Kuala Terengganu, Malaysia: Perspectives for integrated management. *Ocean & Coastal Management*, 163 (2018) 498-514. https://doi.org/10.1016/j.ocecoaman.2018.07.013
13. M.S. Reed, A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C.H. Quinn & L.C Stringer; Who's in and why? A typology of stakeholder analysis methods for natural resource management. *J. Environ. Manag.* 90, (2009) 1933–1949. https://doi.org/10.1016/j.jenvman.2009.01.001
14. J.P. Muller & M. Gavaud; Atlas de la République unie du Cameroun, édition jeune Afrique, Paris, (1979) pp. 25-26.
15. R.G. Dean; Heuristic models of sand transport in the surf zone. In: Proceedings of Conference on Engineering Dynamics in the Surf Zone, Sydney, (1973) 208–214.
16. Komar, P. D. (1974), *Beach Processes and Sedimentation*, Prentice-Hall, Englewood Cliffs, N.J.
17. R. Soulsby; Dynamics of marine sands: a manual for practical applications. London, (1997) 249
18. H. Karunarathna, Horrillo-Caraballo, J., Kuriyama, Y., H. Mase, Ranasinghe, R., & D. E. Reeve; Linkages between sediment composition, wave climate and beach profile variability at multiple timescales. *Marine Geology*, 381 (2016) 194-208. do https://doi.org/10.1016/j.margeo.2016.09.012
19. A.D. Short; Australian beach systems-nature and distribution. *J. Coast. Res.* 22(1) (2006) 11–27
20. E. H. Ariffin, M. Sedrati, M. F. Akhir, N. R. Daud, R. Yaacob, & M. L. Husain; Beach morphodynamics and evolution of monsoon-dominated coasts in Kuala Terengganu, Malaysia: Perspectives for integrated management. *Ocean & Coastal Management* (2018). https://doi.org/10.1016/j.ocecoaman.2018.07.013
21. G. Masselik, A.D. Short, The effect of tide range on beach morphodynamics and morphology: a conceptual beach model. *Journal of Coastal Research* 9 (3) (1993) 785-800

(2020); http://www.jmaterenvironsci.com