Answers to Review #1

This manuscript provides a detailed assessment of changes in the hydrological response of the Wadi Abd, a 2480 km^2 catchment in Algeria, based on a record of precipitation, flow and sediment load extending back over 40 years. Particular emphasis is placed on sediment load, which, looking more generally, has received much less attention than flow. The findings reported are important since:

(a) Their emphasis is on sediment load;
(b) There have been few studies of this nature undertaken on catchments in semi-arid areas and particularly catchments in North Africa;
(c) The catchment has evidenced a shift from perennial flow to intermittent flow, which again has received little attention to date
(d) The lengthy record (40 years) is also an important feature of the study.
(e) The study catchment has not experienced other major changes over the past 40 years due to human impact (e.g. major land use change) and therefore provides a good dataset for evaluating the impact of climate change.

The study builds on a previous paper by the authors published in 2007. This paper dealt with the 22 year record from 1973 to 1995. The current paper covers the 40 year period from 1970-2010 and therefore represents an important update on the previous publication.

Overall, I would suggest that the manuscript is rather 'heavy going' and too long and that the authors should focus on reporting the changes that have occurred in selected key indicators of changes in the behaviour of the catchment. This is what readers are likely to find most useful. I have, for example, indicated below that the discussion of changes in the parameters a and b of the rating curves should be curtailed. I would recommend suggest that the ms should be shortened by about 15-20%. This would strengthen its message. The results presented should be of general interest to readers of HESS.

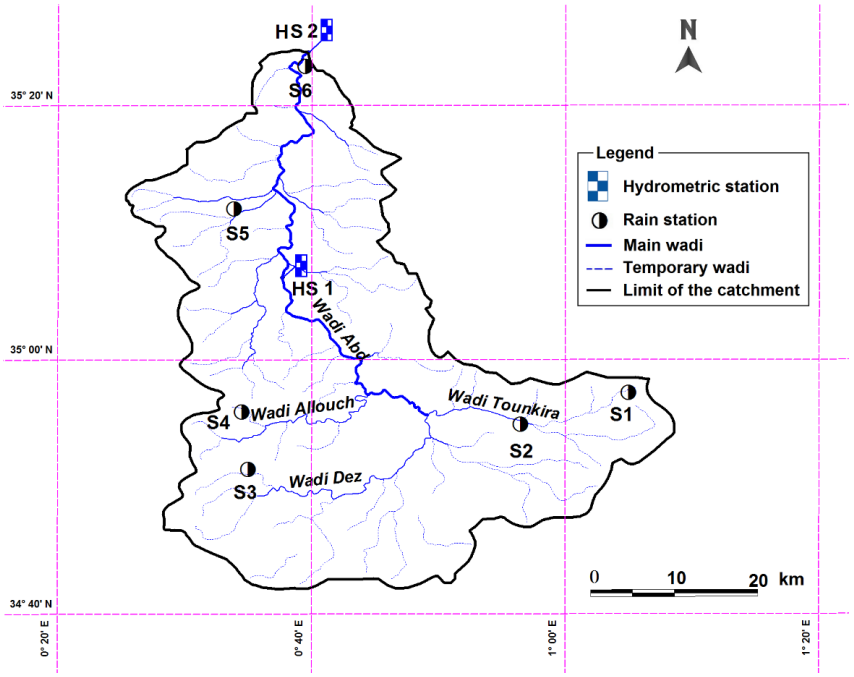
The authors warmly thank the reviewer for his suggestion. The revised version will be shortened (especially in the discussion on (a, b) changes) and will more clearly report the changes in the behaviour of the catchment as well as the associated time scales.

I have little further to say in terms of the analysis and results presented. However, four e issues need further attention.

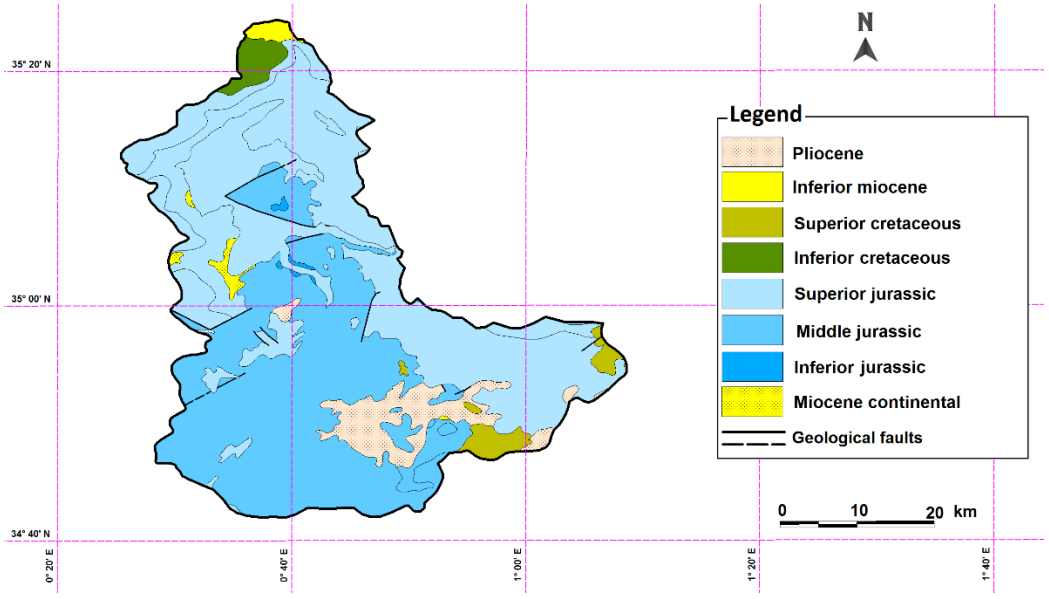
I. Since the ms places emphasis on changes in the sediment yield of the study catchment, section 2.1 should provide a much fuller and clearer description of the landscape of the catchment and more particularly the main erosion processes and sediment sources and their likely relative importance. Is the catchment surface or the channel system the main sediment source. Are there gullies etc etc. Some of this information may be presented in the 2007 paper but I do not think that it is acceptable that the reader has to search out another paper to find key information.

More detailed information that were neither presented in 2007 nor in the submitted manuscript are proposed in the revised version of the paper: maps of geology, slope and vegetation cover (new Fig. 2) and typical examples of linear erosion processes within the catchment (new Fig. 3). A text is also added: "In the plain, sheet (interrill) and rill erosion dominates (Fig. 3 b, f). Gully

erosion is mainly restricted to the mountainous regions of Frenda and Tiaret in the North (Fig. 3 c, d and Fig. 2c), while some mid-slope areas are gullying (Fig. 3 a, e).”

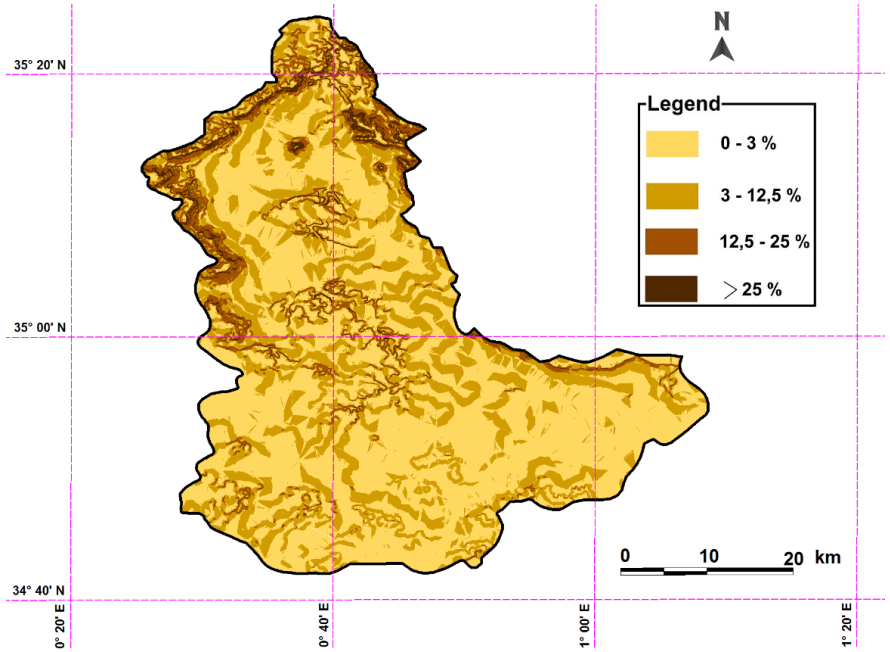


(a)

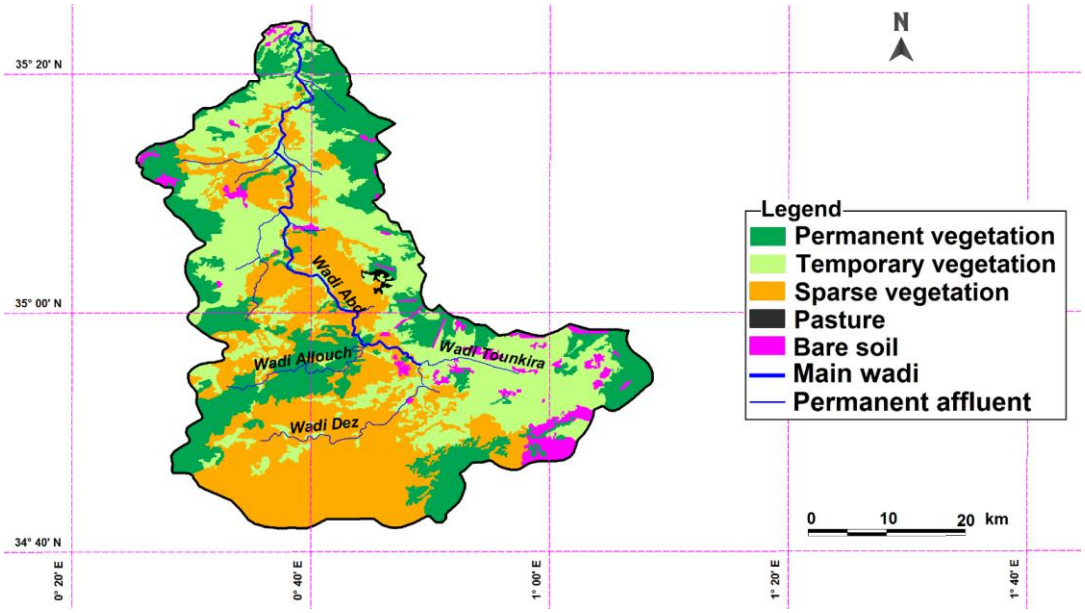


(b)

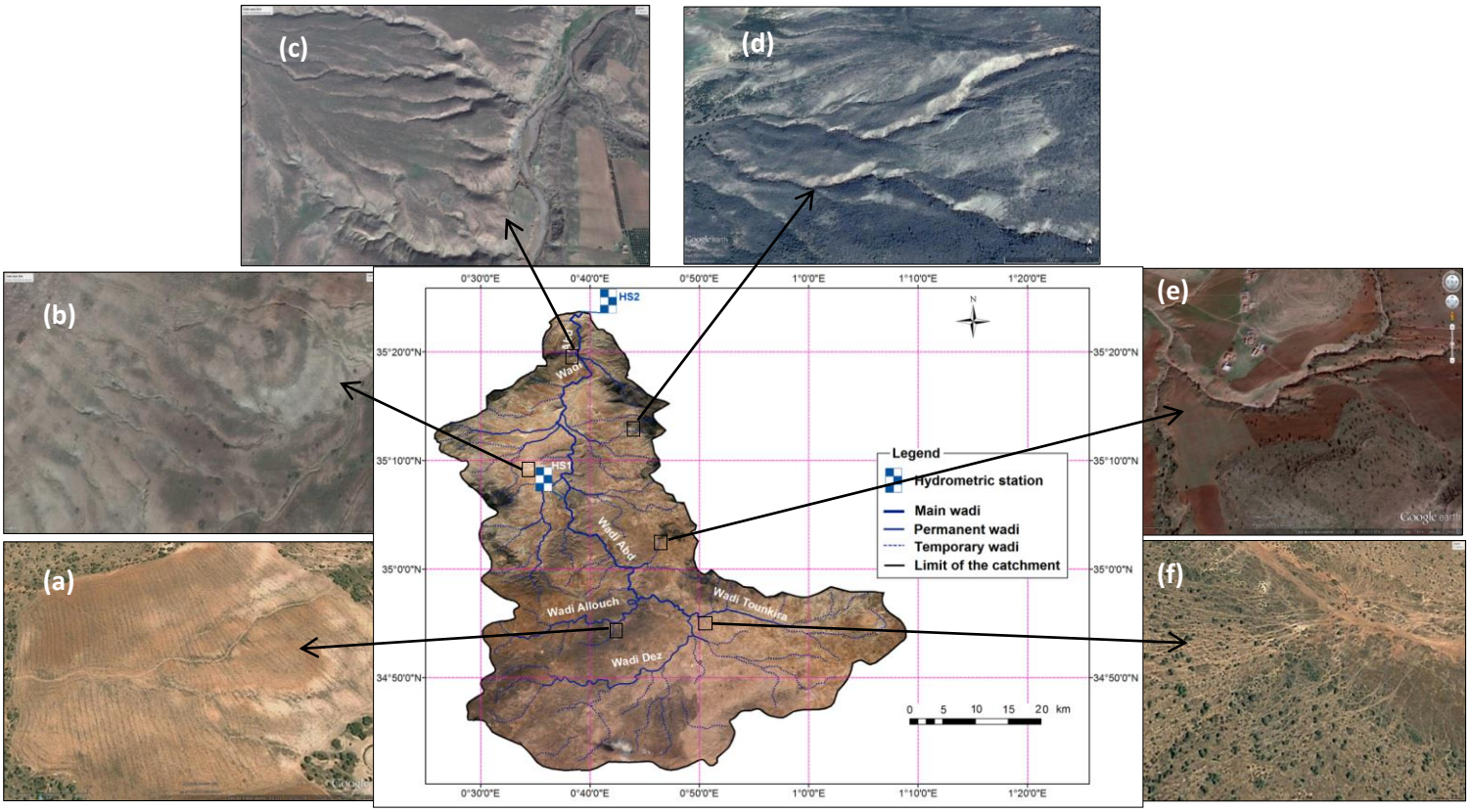
(c)



(d)



(new) Fig. 2 The Wadi Abd catchment area. (a) Rain and hydrometric stations including HS1 at Takhmaret and HS2 at Ain Hamara, (b) Geology, (c) Slopes from the Digital Elevation Model of North Algeria, (d) Vegetation cover from Landsat ETM+ data of 2009



(new) Fig. 3. Linear erosion forms in the Wadi Abd basin. (a) and (e) Gullying (depth: 30-50 cm), (c) and (d) Gully erosion (depth: 50-200 cm), (b) and (f) Sheet (interrill) and rill erosion

II. The authors rightly stress that their study is important because they are able to look at the impact of climate change without having to distinguish this from other human impacts on the catchment. I think that there is a need to provide an explicit discussion of the lack of change in other drivers of the hydrological response of the catchment. Has there really been no land use change? Have there been changes in livestock densities? Has the construction of small reservoirs etc caused changes in the flow regime? This discussion should be linked back to I above.

We are not able to prove that the changes are only due to climate change. If it was the case, the paper would be entitled: “Effects of climate change on sediment load in the Wadi Abd”.

Livestock density is very low (see the new Fig. 2d). This information was added in the following sentence of the conclusion: “The lack of data on land use and land cover changes over 40 years does not allow us to isolate the factors directly related to climate change from those related to other anthropogenic activities, but this question was not in the scope of the paper. The small population, the low coverage of pasture (see Fig. 2d), of cultivated areas and vegetation (43 %) in the basin and the small volume of reservoirs (nominaly 2.3% of the annual discharge, but silted up to 70%) make us think that in this system the effects of climate change dominate anthropogenic effects.“

III. I am concerned that the authors prefer to lump all the sediment data together to produce a rating curve for the entire period which is then used to calculate annual sediment loads. This seems unacceptable when they claim that they are looking at a non-stationary system demonstrating the effects of climate change. This issue needs to be explicitly discussed.

The comparison detailed p.10464 (lines 10-25) between two strategies of rating curve application from one side, and the long-term changes in (a, b) regime which becomes visible with values averaged over 15 years from the other side, rise maybe a main lesson of this study: the non-stationarity of the system occurs at two time scales. The revised version states more clearly the different time scales involved in the change of the basin's behaviour. We add the following paragraph in the conclusion: "The rapid change in sediment regime which is instantaneously driven by the changing flow regime should be distinguished from the slow change in the concentration-flow relationship. The change in flow regime can be precisely dated in May-July 1986 (with 49 consecutive dry days), while the change in the C-Q relationship needs averaging over 15 years of a, b and specific sediment yield to become evident. Such inertial effect may be attributed to the time for the basin soil properties (such as humidity) or vegetation to adapt to the new climate conditions. It likely depends amongst other factors on the underground water storage, and thus on basin lithology and infiltration history. On the Wadi Abd basin, the time needed for the flow regime to change after the dryness settlement in early 1970's (see Fig. 4) is around 15 years."

Anyway, the new figure 5 (previous Fig. 3) shows that the use of one single relationship over 1970-2010 is suitable to reproduce the variations of daily C from those of daily Q.

IV. I found the discussion and interpretation of the parameters a and b in the sediment rating curve unconvincing and contrived. I would strongly suggest that this part of the manuscript should be deleted or at least greatly reduced. I do not believe that these two parameters provide information on the relative importance of the catchment surface and the channel system in controlling catchment response. The authors suggest that the changes in a and b reflect increased erosion of the watershed and decrease in the erosive power of the river. I would see the changes in a and b and simply reflecting the shift of the river regime from perennial flow to intermittent flow. As a result of this change flows will decline to zero and sediment concentrations associated with lower flows during storm events will increase. Parameter a represents the concentration associated with a flow of 1. Since flows decline to zero after storms, high concentrations can be recorded at low flows on the rising limb of the hydrograph when flow resumes during storm events. Therefore parameter a will increase. There is no need to invoke a increase in erosion within the watershed. If parameter a increases the slope of the line (i.e. b) will inevitably decrease. Again there is no need to invoke a change in the erosive power of the river. The authors refer to the work of (Wang et al. 2008) on the Yangtze below the Three Gorges Dam as providing further evidence of the potential to use the two parameters to identify changes in the relative contribution of the basin surface and the river. Dam construction is a special case, which is very different from the response of a more natural catchment. If a dam is constructed upstream, the suspended sediment load and concentration are likely to decline due to sediment trapping by the dam. As a result sediment concentrations for a given flow will decline and a would decrease. If a decreases, b is likely to increase and this will also reflect scour

of the channel below the dam during high flows due to the low sediment load (i.e. Kondolf's hungry water) which will reduce any decline of sediment concentrations at high flows.

Part 7.4.1 was curtailed and the discussion on the relative importance of the catchment surface and the channel system in controlling catchment response was deleted, as well as the reference to Wang et al (2008). The conclusion was also reduced on the interpretation of a and b values, and the reference to Trimble (1999) deleted.

My remaining comments relate, firstly, to the need for revision to deal with the use of terms which are likely to be unclear to native English speakers and which probably reflect terms used in France and, secondly, to other improvements in the text and minor queries. The terms that need attention are:

(a) RUPTURE This term is used very frequently in the ms. to refer to break points or change points in the double mass curve and similar contexts. Its use with this meaning will not be familiar to readers of the ms. 'Shift' is a word that might be appropriate in some places.

Thanks. It was corrected.

(b) The term SPECIFIC DEGRADATION, although commonly used in French (degradation specifique) will not be familiar to most readers. If the term 'sediment yield' is used for the total load i.e. t $year^{-1}$, then the term specific sediment yield should be used to refer to t km^{-2} $year^{-1}$.

Done

(c) SEDIMENT WASH-DOWN (page 10460 line 3) It is not clear what you mean by the ratio of sediment wash-down to river discharge. What is sediment wash-down. What is the ratio? Is it effectively load/discharge i.e. concentration?

Yes, it is the ratio load/discharge i.e. concentration (10.7 g L^{-1} over 22 years in AO2007). The correction is done.

(d) AGGLOMERATIONS Page 10461 line 25. What are agglomerations?

"Cities" (sorry, we let the French word in the submitted version). Corrected.

(e) GAPS On line 11 page 10471 you use this word when you really mean 'differences'

Corrected

(f) UNDERGROUND WATER LAYERS You refer to this on line 6 page 10472. I think you probably mean 'underground storage'.

Corrected

(g) PARTICLES not PARTICULES (page 10481 line 15).

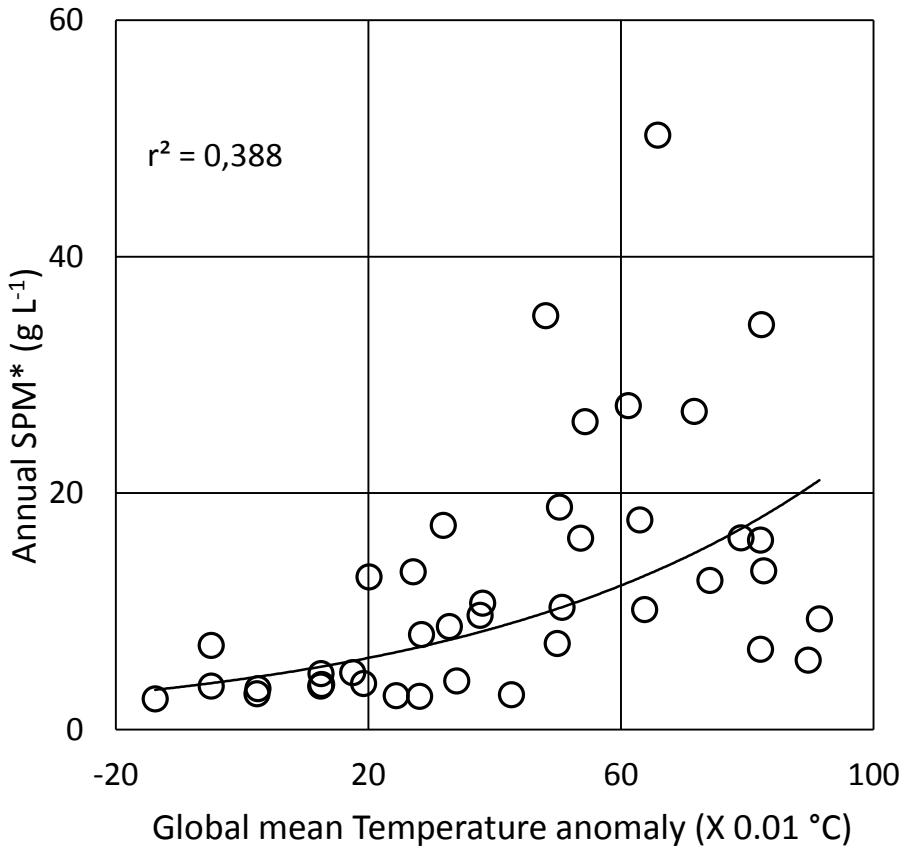
Thanks. Corrected

There are many other instances of poor English which need to be dealt with. The ms needs careful editing by a native English speaker with expertise in hydrology. It may be necessary to make use of commercial scientific editing service. Some suggested corrections and comments are listed below.

1) Page 10458 line 14. 'scatter' of what?? "of the C-Q pairs" (added)
2) Page 10459 'patterns involved in' change this to 'factors controlling' Thanks. Done.
3) Page 10460 line 26 Change to 'relationship between sediment load and runoff over…' Thanks. Done.
4) Page 10463 lines 1-3. It is not clear how the mean daily values are obtained from the instantaneous values. There is a need to specify key procedures used and not to expect the reader to search out other papers to find this information.
   The text was changed into: "From these 9076 coincident instantaneous data measured during 1213 days, average arithmetic values were calculated per day so as to obtain 1213 pairs of "mean daily" (C, Q) values. The resulting "mean daily Q" differs from the (true) daily discharge obtained from the averaging of 24h of continuous instant Q."
5) Page 10464. Lines 10-25. The argument here seems counterintuitive and questionable. I do not think it is acceptable to use a rating relationship developed for the 40 years of data when the system is clearly not stationary. You are identifying important changes but then apparently ignoring them by using a lumped rating relationship.
   See issue III above.
6) Page 19465 line 3. 'to understand better..' Avoid the spilt infinitive. Thanks. Done.
7) Page 10468 line 3. Avoid using the words 'sediment delivery' since they are often used to refer to the processes operating between sediment mobilisation in the catchment and the sediment load at the catchment outlet i.e. conveyance losses and storage. You are referring to sediment output, sediment load or sediment yield. Thanks. We changed to "sediment load" or "sediment yield" all along the paper.
8) Page 10469 lines 1-3. It is not clear why you need daily values of concentration and discharge to calculate average values of SPM*. If is this is load -weighted mean (i.e. Load/Discharge) you need to make this clear. You also need to make it clear whether the daily concentration data are measured data or extrapolated values obtained using the rating curve relationship. You're right. SPM* is the load weighted mean and can be obtained from daily values but also from weekly, monthly, seasonally or directly yearly values of Q and Qs, since SPM*=Qs/Q. The lines are changed into: "The average value of SPM* calculated over the period 1970-2010 is 12.3 $g.L^{-1}$. The 40 annual values of SPM* calculated for each year from measured discharges and concentrations estimated using the rating curve (3) vary between 2.5 $g.L^{-1}$ and 50.2 $g.L^{-1}$"
9) Page 10469 lines 24 and 25. The wording needs improving. I think that you mean '..showed that, over 22 years, 71% of the variance of the annual SPM values …..was accounted for by the annual discharge.. and 73% by the 95th percentile … '' Thank you. Corrected as suggested.
10) Page 10472 line 5 '…runs into…' Line 14 reword '..and the water level in the aquifers will be lowered.' Line 26 '…suspended sediment loads were greater in the autumn during the 2000s..'Lines 27-28 reword to ' shifted from……..to a regime with one dominant season in the 2000s'. Thanks. Done.
11) Page 10475 Line 9 'the Maghreb' Line 10 '…correlated with..' Line 14. Do you mean '..on the highest discharges than on the average discharge'. Line 27 '…of 0.226 when correlated with …' Thanks. Done.
12) Page 10476 line 2 'is responsible for..' Lines 6-7 'consequences for'. Done. Line 24. It is not clear what is meant by 'averaged per decade'. How can a single value of average flow provide information on the date of the first flood? We added and corrected the first sentence following: "The analysis of the time series of daily flows enables to determine the start of the first summer

flood. The average daily flow per decade suddenly increases the day at which the first summer flood occurred, at least once in the decade. By observing these decadal averaged daily flows, there is no ambiguity on the start of the earlier flood by decade."

13) Page 10477 Line 1 'starts on average on the 6th September…' Line 4 ' the first flood of summer'. Line 8 'was observable'. Line 10 'gave the following results for…'. Done. Line 24. Give reference for NQAA. 2 references were added (Hansen et al., 2010; GISTEMP Team, 2015) as requested by NASA. By error, the previous Figure 13 showed only 22 points corresponding to 1973-1995. A new Fig. 13 is provided in the revised version and the r^2 value (0.388) is changed accordingly in the text:



Ref. added:

GISTEMP Team: *GISS Surface Temperature Analysis (GISTEMP).* NASA Goddard Institute for Space Studies. Dataset accessed 2015-12-08 at http://data.giss.nasa.gov/gistemp/

Hansen, J., Ruedy, R., Sato, M., and Lo, K.: Global surface temperature change, Rev. Geophysics, 48, RG4004, doi:10.1029/2010RG000345, 2010

14) Page 10478 Line 3. Please check the Langbein and Schumm paper. I think the relationship was with annual effective rainfall rather than annual rainfall. The two are different. You're right. We changed the text into: "Many authors studied the variations of sediment load per unit of catchment area against annual rainfall (e.g. Summerfield and Hulton, 1994) or effective rainfall (e.g. Langbein and Schumm, 1958)" and added the following reference:

Summerfield, M.A., Hulton, N.J.: Natural controls of fluvial denudation rates in major world drainage basins, J. Geophys. Res., 99 B7, 13871-13883, 1994.

Line 18 ‘fluvial sediment rather than ‘riverine sediment’. Done.

Line 23. It is not clear what is meant by ‘parameter evolutions’ The text was changed into: “Although the river regime shift clearly impacted several parameters between the two periods”

15) Page 10481 line 3 ‘after’ rather than ‘posterior to’ Done.

16) Page 10482 Line 6. ‘favour’ and ‘as a sediment source..’ Line 16 ‘correlation with…’ Done.

17) Page 10483 line 2 ‘estimation’? line 5 ‘coefficient of determination’. Lines 6 and 7. ‘..established for only the last decade did not provide a reliable estimate of the soild discharge….’ Line 17 reword ‘…rating curves, water discharge must be recorded at frequent intervals, although measurements of …’ Done.

Line 23 meaning of ‘advance’ not clear. The text was changed into: “rainfall moved forward during the late warm season and the watershed of Wadi Abd experienced a significant change”

Line 24 ‘..increased variability at both the inter-annual and intra-annual levels. Done.

18) Page 10484 lines 9-12. As noted above you need to provide some indication of the likely relative importance of the catchment surface and the channel system as sediment sources. The discussion on the sediment sources (catchment surface or channel system) was deleted in the new version of the paper. Line 18 . What are INSTANT models?? “instant” was deleted. Line 23 Should it be ‘marl’? Yes. Correction done.

19) Page 10485 Line 1 wording needs correction. ‘..makes us think that…’ Line 20 ‘due to..’ Done.

20) Page 10486 line 2 ‘..in the Maghreb..’ Done.

21) Page 10496 Table 2 avoid the term specific degradation - refer to specific sediment yield. Degradation could involve chemical weathering. Thanks. Correction done.

22) Page 10497 Table 3 title. Delete ‘sediment delivery’ and insert ‘sediment output’ or ‘sediment yield’. Done.

23) Page 10499 Figure 2 title. ‘…mean annual temperatures…’ Done.

24) Page 10502 Figure 5 title. See 22 above. Done.

25) Figure 6 title. Refer to ‘flowing water’ not ‘running water’ . Running water comes out of a tap! Thanks. Done.

26) Page 10504 Figure 7 y axis. The units cannot be t. It must be a multiple of t. The unit should be tonnes not tons. Sorry, the unit is 10^6 metric tons.

27) Page 10505 Figure 8 title. Find an alternative term to ‘sediment delivery parameters’. As indicated above, do not use ‘specific degradation’ in the title and on the y axis Bb. “sediment delivery” was corrected into “sediment load”, and “specific degradation” by “specific sediment yield”

28) Page 10506 figure 9. Change labelling of y axis in Fig. 9C to ‘Seasonal contribution to mean annual sediment load (%) (9 year average). Done.

29) Figure 13 title. Provide a reference to GSS Done (see also comment 14 above)

30) Page 10513 The key should refer to r2 and not R2 . You are plotting simple bivariate relationships. R2 is used for multiple correlation. Done on every figure.