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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Potential of kite-borne photogrammetry for decimetric and kilometre square 3D mapping: an application for automatic gully detection" *by* Denis Feurer et al.

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REVIEWER Review: Please find herein the review of the paper : "Potential of Kite-borne photogrammetry for decimetric and kilometre square 3D mapping : an application for automatic gully detection" submitted to discussion by Denis Feurer et al.

Generally speaking : This paper deals with the acquisition and application of very high resolution topographic data through a kite using photogrammetric methods on a very local area where it is difficult to get authorizations to fly for UAV. The methodology is well described. An interesting discussion on photogrammetric errors is also given. Finally an application on the mapping of small gullies in the Cap Bon (Northeastern Tunisia)

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Discussion paper

is slightly evocated as an application. This paper is interesting even if the authors miss some important references both in remote sensing acquired through Kites since 1870 (since the Jean-Felix Tournachon-Nadar - acquisitions through the same kind of settings to survey military puposes in the Paris city during the "Commune") and on the VHR DTM as plenty of works had already been done and published in Geosciences since for instance the last five years. An effort on the bibliography is herein definitely needed in order to be less French IGN/IRD oriented !

AUTHORS RESPONSE: We warmly thank the reviewer for the helpful comments and the remarks throughout the whole text. We agree with the remarks of the reviewer asking for more precision about the way our work contribute to the existing litterature and we did new efforts - in particular on the cited bibliography - in order to answer this recommendation. These corrections are proposed below as answers to detailed remarks of the reviewer. For some points we proposed new or corrected figures (see below) and rewritten tables/sections (they appear in the suplementary material file attached to our comment). For each item, the remark of the reviewer is taken back after the word REVIEWER and the answer of the authors is given after the words AUTHORS RESPONSE. Any proposed revised or added text is given between quotes after our answer. Please note specific numbering of Figures in this document ; additionaly, captions longer than 200 characters are truncated below theses figures, complete caption are given in the text, however.

REVIEWER The plan of the paper is correctly exposed but several times it is needed to precise and even to rewrite some paragraphs in order to prevent to look for solutions in the following part of the text... Some figures could be easily improved for the topic of the paper. To my point of view this paper should be published in an NHESS issue but with major revision that takes into consideration different points listed above and below.

AUTHORS RESPONSE: Again we concur with the points raised by the reviewer and we propose hereafter complete rewriting of several paragraphs, and of the requested figures and table captions. We also proposed corrections to several figures and an

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additional figure describing more precisely the gullies mapping technique. All these new submissions are detailed below according to each precise remark.

REVIEWER Into more details : P1: Abstract: Should be locally rewrite in order to expose the reasons why authors used kites and not UAV in that area (facility to fly/low costs/low administrative regulations, etc).

AUTHORS RESPONSE: We propose to rewrite and expand the (p.1 l.4) to develop theses reasons: "Kites were used because they propose an interesting alternative solution to unmanned aerial vehicles (UAV). First, kites remain tethered to the operator. Thus they are more secured and less affected by administrative regulations. Then kites are not remotely piloted so flying kites necessitate very few piloting skills or technological equipment. Finally, kite aerial photography is robust and cheap in comparison with the use of UAV-based photography."

REVIEWER p1: No needs to give such details in an abstract (line 7-8), simplify lines 11 to13.

AUTHORS RESPONSE: We understand that too much details bother the understanding of the whole abstract. We hence propose to remove the line 7-8 and to re-write lines 11 to 13 as follows: "It allowed to obtain a decimetric DEM covering more than three square kilometers. Altimetric accuracy was 0.07m and precision (standard deviation of the error) was 0.22m."

REVIEWER P2: 1. Introduction/context : Please cite major authors who used kites in the passed to get informations. Youare not the first ones to do so...

AUTHORS RESPONSE: We propose to enhance bibliography about previous authors who used kites in the "KAP" section of the introduction ; the proposed text is to be found below with our proposed answer to REVIEWER comment about p.4 l.1

REVIEWER p2, l6: "... remains difficult" WHY ? p2, l6: "...Such a race... ? p2, l7: "... coarser data ?"

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AUTHORS RESPONSE: We propose to modify these sentences in order to make the beginning of this section more clear to the reader. We hence propose to modify p2, l5-8 as follows: "... towards larger and higher-resolution DEMs. Such topographic data - with submetric features and covering large areas - is of great relevance for erosion science and in particular for gully erosion. Because the study of gully erosion requires such detailed topographic data, research work based on field surveys must concentrate either on a few gullies with high-density topographic data, or on an entire gully system with metric or pluri-metric data. As a side effect, ..."

REVIEWER p3: l11: "...several others PRECISE

AUTHORS RESPONSE: We propose to re-write the p.3 l.10-11 as follows : "For an overview of the SfM-based photogrammetric workflow, the reader is invited to consult sections 1.2 and 1.3 of Westoby et al. (2012) or Fonstad et al. (2013), page 422."

REVIEWER p3, l12: the calculation of 3D objects PRECISE

AUTHORS RESPONSE: For more clarity, we propose to change the current wording of this sentence by the following: "... oriented towards 3D rendering."

REVIEWER p3, l13 and l14: PhotoScan (R) It is needed to be coherent with the same way to write the same softwhere everywhere in the ms.

AUTHORS RESPONSE: The reviewer is perfecftly right. Moreover, after new checks, to be compliant with the way this software is cited in the litterature, we propose to remove the date and the academic way of referencing this software and to restrict the wording to these two words: "AgiSoft PhotoScan"

REVIEWER p3, l19: "... and proved equally satisfying PRECISE

AUTHORS RESPONSE: We propose to complete the sentence by adding the following words : ".. and proved equally satisfying in terms of precision, both software achieving a 3-4cm precision using images with spatial resolution of 1.7cm per pixel".

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REVIEWER p3, l26"For instance, Harwin...

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript.

REVIEWER p3,l31-32 ...in the IGN and IRD field of Geosciences. Precise IGN and IRD. Numerous studies has been done in the world on Geosciences since the last five years using VHRDTM/DEM...

AUTHORS RESPONSE: We agree with the reviewer that the study of VHR images is a very active field of research and that the way this paragraph was written can give confusion about the relation between our work and this part of the litterature. For this single sentence (p.3 l31-32), we propose to remove it. Moreover, another remark of the reviewer later in the manuscript (p.10, l.3) is somehow in the same line and we indeed agree with the fact that more references to existing work will greatly help the reader. We hence propose, in order to answer these two constructive remarks, to re-write the "Goal" section of the introduction (p.2, l17-23 of the submitted manuscript) with more precision about the way our work contributes to this field. This also implies a re-writing of the 2.5 (gullies mapping) section (p.9 and 10), to which we also propose to give additional information in response to the recommendations of reviewer 1. However, to our best knowledge, few of past work aims at detecting gullies automatically. Moreover, contrarily to our method, they may fail at locating all the gullies (e.g best detection rate of 73% in Desprats et al., 2013), which is the goal of gullies detection in this study. We propose to mention this information along with others references to past works by replacing the last 5-6 lines of the "Goal" section of the introduction by the following text :

"The DEM is devoted to the study of erosion features and erosion processes, including the delineation of every single active gully in the watershed. It is worth noting that several methods of automatic erosion mapping, such as methods based on summit level surface, or similar morphomathematic methods like Top Hat (Rodriguez et al. 2002) would have embedded indistinctly large ravines where erosion ceased for long

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and active gullies, the localisation of which being our goal. For instance, among other automatic methods Desprats et al. (2013) failed at detecting all gullies and Noto et al (2017) only aims at providing estimates of gully erosion patterns. Compared to such works, the goal of this test is to show that it is possible to locate every single gullies on a decimetric DEM, almost like an expert would do on the field. On the field, a gully is a portion of the hydrological network characterized by a sharp depression which is discordant with the smoothness of the surrounding topography. Mapping gullies therefore consists in two steps: first, localize sharp depressions in the landscape, then localize the hydrological network. A sharp depression crossed by the hydrological network will subsequently be categorized as a gully. As mentionned above, subtracting a smoothed version of the DEM to the raw data has been a common procedure, used for a variety of purposes. Most lately, in the field of archeology, Nykamp et al. (2017) used it to extract a local relief model. Vandrome et al. (2017) used the method for mapping artificial drainage network. Luethie et al. (2017) used it to extract land cover features. Finally Bonetti and Porporato (2017) smoothed of the topographic surface and subtract it to the original surface in order to reproduce erosion or deposition, which is basically what our method is aimed at. Concerning network detection, algorithms are many and amongst them, the one proposed by Passalacqua et al. (2010) appears as a reference. Using very high resolution topographic data, it detects gully heads from curvature information and then delineates networks by descending the DEM from gully heads. Gully heads detection remains the most challenging part, notably for very small features (Orlandini et al. 2011), due to the intrinsic drawbacks of methods based on contributing areas (Pelletier, 2013). As a consequence we use a method which combines the main advantages of existing algorithms and takes into consideration field expertise in order to achieve exhaustive mapping of active gullies. Although the paper is primarily a description of the method used to measure and calculate high-resolution topography at large scale, a brief example of this application is presented at the end to demonstrate the potential of such data for the delineation of erosion features. The paper first demonstrates how and why a precise positioning of the kite can be achieved.

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It then presents the resulting DEM along with an assessment of its overall quality. Finally, preliminary results on the delineation of gullies are presented to illustrate the potential of decimetric DEMs at large scale."

New references: Rodriguez, F., Maire, E., Courjault-Rade, P., and Darrozes, J. (2002), The Black Top Hat function applied to a DEM: A tool to estimate recent incision in a mountainous watershed (Estibère Watershed, Central Pyrenees), Geophys. Res. Lett., 29(6).

Desprats, J. F., Raclot, D., Rousseau, M., Cerdan, O., Garcin, M., Le Bissonnais, Y., ... & Monfort-Climent, D. (2013). Mapping linear erosion features using high and very high resolution satellite imagery. Land Degradation & Development, 24(1), 22-32.

Noto, L. V., Bastola, S., Dialynas, Y. G., Arnone, E., & Bras, R. L. (2017). Integration of fuzzy logic and image analysis for the detection of gullies in the Calhoun Critical Zone Observatory using airborne LiDAR data. ISPRS Journal of Photogrammetry and Remote Sensing, 126, 209-224.

Nykamp, M., Knitter, D., Timár, G., Krause, J., Heeb, B. S., Szentmiklosi, A., & Schütt, B. (2017). Estimation of wind-driven soil erosion of a loess-like sediment and its implications for the occurrence of archaeological surface and subsurface finds–An example from the environs of Corneşti-Iarcuri, western Romania. Journal of Archaeological Science: Reports, 12, 601-612.

Bonetti, S., & Porporato, A. (2017). On the dynamic smoothing of mountains. Geophysical Research Letters.

Vandromme, R., Foucher, A., Cerdan, O., & Salavador-Blanes, S. (2017). Quantification of bank erosion of artificial drainage networks using LiDAR data. Zeitschrift für Geomorphologie, 61(1), 1-10.

Luethje, F., Tiede, D., & Eisank, C. (2017). Terrain Extraction in Built-Up Areas from Satellite Stereo-Imagery-Derived Surface Models: A Stratified Object-Based Ap-

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proach. ISPRS International Journal of Geo-Information, 6(1), 9.

Passalacqua, P., Do Trung, T., Foufoula-Georgiou, E., Sapiro, G., & Dietrich, W. E. (2010). A geometric framework for channel network extraction from lidar: Nonlinear diffusion and geodesic paths. Journal of Geophysical Research: Earth Surface, 115(F1).

Orlandini, S., Tarolli, P., Moretti, G., & Dalla Fontana, G. (2011). On the prediction of channel heads in a complex alpine terrain using gridded elevation data. Water Resources Research, 47(2).

Pelletier, J. D. (2013). A robust, two-parameter method for the extraction of drainage networks from high-resolution digital elevation models (DEMs): Evaluation using synthetic and real-world DEMs. Water Resources Research, 49(1), 75-89.

REVIEWER p4, l1 : KAP, please cite those who had acquired remote sensing data from that kite-vector through the bibliography.

AUTHORS RESPONSE: We propose to add the following lines p4, l.6 and to modify the beginning of the next sentence as follows : "In their recent review - after having reminded the very long and pionneering history of remote sensing by kites - Duffy and Anderson (2016) list a good portion of these. From this list we can cite the works of Boike and Yoshikawa (2003), who map geometric periglacial features in Alaska and Verhoeven (and in particular its 2009 article) who pursues nowadays the ancient tradition of using kites in archaeology. More specifically, the works of Smith et al (2009) and Bryson et al. (2013, 2016) have to be cited in addition to the one of Marzolff and Poesen (2009) for their use of kites with a view of precise topographic mapping of small areas. However, much more - in particular in terms of area covered - can be done by kite if one considers that the kite ..."

REVIEWER p4, l28 Please give slope angles in degrees not in %.

AUTHORS RESPONSE: This will be corrected.

REVIEWER p4, l29: "... several hundred decimetric to pluri-metric size gullies

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AUTHORS RESPONSE: Thanks, this will be changed in the revised version of the manuscript

REVIEWER p4, l29: "the outlet...small hill dam... is this dam an outlet or a local base level ?

AUTHORS RESPONSE: For more clarity, we propose to change the sentence into "In 1994, a reservoir of 140 000 m3 was built at the outlet of the watershed"

REVIEWER p4, Fig.1. Please optimize the location of the cap bon not in both N and S world hemisphere but located in Tunisia. a quadrangle with the bird's eye view of Cap bon, Tunis and the studied area would be better. Please add Latitudes/Longitudes + graphical scale, as well as the north and develop a bit the text of the legend of the figure: what is important herein ?

AUTHORS RESPONSE: We propose (see Fig. 1 of this document) a new version of this illustration taking into account the recommendations of the reviewer. The proposed new caption would be : "Location of the Kamech test site and available ground truth data. (a) Location of the Cap Bon peninsula, in the north east of Tunisia; Kamech test site is marked in red. (b) close-up on the Kamech watershed, 263ha, delineated in red ; scale is given by the black scale bar; the lake is visible in the south-east of the catchment. (c) close-up on the available ground truth data around the lake; scale is given by the external graduations (projection UTM, EPSG:32632); the dam is the oblique linear feature visible on the south east side of the lake; the dam outlet is at the northern extremity of the dam, near the most eastern cross. The ground truth data set is composed of Ground Control Points (crosses), used to give spatial reference to the image data set, and validation points (black dots), used to independently validate altimetric information (DEM) computed from the image data set"

REVIEWER p4., l30: What is the time of the dam construction ?

AUTHORS RESPONSE: The hill reservoir was built in 1994. We proposed above to

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add this information in the rewritten (p.4 l.29-30) sentence

REVIEWER p.5, l4: Unclear "global inclination" is it the dip of the strata ? is the topographic slope higher or lower than the dip of the strata ?

AUTHORS RESPONSE: We propose to change the (p.5 l.4-5) sentences by the following ones: "These layers have a global south-east dip of approximately 30° corresponding to the global anticline of Cape Bon. The right-bank side of the catchment shows a natural slope globally parallel to this dip and presents mainly marly layers. Hence most gullies have developed on this side. Sandstone bar outcrops can be seen on the left-bank side of the catchment (Figure 1-c)."

REVIEWER p6, It is unclear to me if the authors used different 4, 6, 10m2 kites or one which may adapt to the local wind conditions in terms of flying surface. Please precise and probaly re-write that part to make it clearer through the ms. p6, l5: Please precise the wind conditions and line lengths or cite the table 1 here.

AUTHORS RESPONSE: Indeed the text (plus the confusion arisen by the mistake on submitted figure 6) has to be precised. We did had two delta kites, one with a 4m2 wing and another with a 10m2 wing, as given in Table 1. We propose to rewrite the (p.6 l.5) sentence this way: "First, two delta kites (one with a 4m2 wing and one with a 10m2 wing) were flown within different wind conditions and with different line lengths (see Table 1)."

REVIEWER p6, l7: Precise what you call ...kite remains stable... (no drags for instance)

AUTHORS RESPONSE: "Stable" means that the kite keeps being in the same position, without shocks nor sudden movements. We propose to precise this by changing the (p.6, l.7) sentence as follows: "This information also allowed us to check for the ideal windrange in which the kite remains in a stable position, with a steady flight angle, and without shocks nor sudden movements during the flight."

REVIEWER p6, l10: Please precise how you measure the Beaufort wind intensity

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without anenometer (waves on the lake ?)

AUTHORS RESPONSE: Beaufort wind intensity can be estimated by observing what happens on water surfaces or on land surfaces. We specifically observed effect of wind on land : how did the wind moved small branches or raised dusts for instance. Several ressources can be found, from encyclopedies or from national meteorolgical offices (see https://en.wikipedia.org/wiki/Beaufort_scale#Modern_scale, https://www.rmets.org/weather-and-climate/observing/beaufort-scale, http://education.meteofrance.fr/ressources-pour-les-enseignants/observer-et-mesurer/le-vent1#,...). We propose to add the following words to the (p6, l11) sentence to make it more clear: "... estimated from direct observation of land conditions (moving branches, raised dust,...) and does not require any anemometer."

REVIEWER p6, l11: In field => in the fields...

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

REVIEWER p6, l14 Why is the diameter of the line is that important ? Could you give the weight of both lines (e.g. /m2 or for the used length) ?

AUTHORS RESPONSE: Apart from the weight (data expressed in g/m for both lines have been given both in text on p6, l.12 and in the caption of submitted figure 4), line diameter is important because of the induced drag. As stated p.6 l.15, effect of drag has been looked by simulating line shapes with real lines (drag and weight) and with ideal lines (no drag and no weight). In order to make the text more clear, we propose to complete the sentence on p6, l14 by the following words: "...smaller diameters, which implies a lighter line and less drag on the line."

REVIEWER p7, l7 Precise what is the Yaw angle, show it on Fig.2.

AUTHORS RESPONSE: We propose to complete the figure as requested (see Fig. 2 of this document) and complete the (p.7, l.7) sentence by the following words:" "... yaw angle, which is for the rotation angle around the vertical axis of the tripod." The

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proposed modified caption is as follows: "Left: schematic principle of acquiring images by kite with a steady flight angle. Right: Tripod with camera: (a) intervallometer ; (b) camera ; (c) GPS. The yaw angle is the angle around the Z axis."

REVIEWER p7, l10: Compromise between weight, image quality and cost... could you give indications of the min, average and max of each ?

AUTHORS RESPONSE: Even if evry criteria cannot be quantified, we indeed thought, in a previous draft version of the paper, of providing a table that would have made this compromise more explicit. We propose to put this table back in the revised version of the manuscript. Proposed new Table X and its caption appear in the supplementary material file.

REVIEWER p7,l11: Why is it important to disable the image stabilizer ?

AUTHORS RESPONSE: All the more the camera optic remains fixed during acquisition, all the more the autocalibration process is succesful : with more fixed parameters, a simpler camera model can be estimated and camera model estimation is more robust. We added this information in the caption of the proposed new table and we propose to add this information in the text at p.7 l.12:" "Fixed optics are indeed necessary to be able to properly and robustly estimate camera model during lens autocalibration performed in the SfM approach."

REVIEWER P.7: Did you have any accidents/problems with the rig ? could you explain and give more informations on your experiments on flying such a large kite for NHESS readers.

AUTHORS RESPONSE: When using simple and strict security procedures and adapted equipment, one should avoid easily the main problems linked with the considerable pull that large kites can have in a strong wind. One critical point is that the stronger the wind, the stronger the kite pulls and the faster things go so the quicker the operator must react. The only problems we had were in such cases. It consisted in

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line going too fast and "burning" clothes or hands/arms, the winder which temporarily slept out our hands, the kite going bad when temporarily not looking at it. As a consequence, it should be advised to beginners that in such cases it may be clever to decide not to fly a kite if they don't feel experienced enough. Thus we do agree with the reviewer that such information is of a great interest for NHESS reader and propose to add the following lines at (p.7 l.17): "Flying large kites, especially in strong winds, can raise security issues. The only problems we faced were under conditions of strong winds. It consisted in small burns on hands/arms or clothes when the line was going too fast, or having the winder temporarily slept out our hands during a wind gust. It also happened that kite went really bad in very strong winds when not looking at it during several seconds and moving upwind. To avoid easily the main problems, the following security measures can be given : 1. Protect yourself and other people : make sure the zone downwind any light and large equipment is always clear of any people as it is a dangerous zone ; use gloves and more generally covering clothes 2. Danger and necessary skills grow with wind strength : a clever decision may be not to fly if conditions are not OK 3. Flying gear must always be secured (attached with hooks for instance) 4. The operator must keep looking at its equipment and at surrounding people for the security of everyone"

REVIEWER p7., l22: Please precise how was acquired the GCP's ?

AUTHORS RESPONSE: We propose to do the following changes to make it more clear : p7, l21-22: "... eight points (cross marks on Figure 1) were visible in images and could therefore be used as Ground Control Points (GCPs). These GCPs were used to give spatial reference as an input to the photogrammetric image processing step described in the following section." p7, l25-26: "All these points including GCPs were measured with a Topcon..."

REVIEWER p7, l27: however (and not howver)

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

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REVIEWER p7, l32 Data instead "figures" ?

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

REVIEWER p7, l32: precise security reasons ? unclear

AUTHORS RESPONSE: We propose to cut and develop this sentence as follows: "However, the very upstream part of the catchment could not be covered. Indeed, a power line is crossing the catchment in that place and we strictly avoided to have the kite line in close proximity to this power line."

REVIEWER p8, table 1 precise the difference calibration/acquisition and comment of the table.

AUTHORS RESPONSE: We propose to change expression "calibration" by "kite characterisation" and to precise "acquisition" with "image acquisition" and to develop the table caption as follows: "Flight conditions for kite characterisation and image acquisition flights and characteristics of the photogrammetric survey. The first flights did not aimed at acquiring images and only at characterising the kites behaviour." We propose also to modify the table accordingly, the resulting table is in the supplementary material file.

REVIEWER p8, l7:... is reached. precise how to define the optimal ground resolution of the DTM toward the resolution/precision of the acquired dataset...

AUTHORS RESPONSE: MicMac computes the DEM at the mean ground resolution of images, which is estimated from the average flying height. This average flying height is estimated from mean flight altitude and the average altitude of SIFT points. We propose to add the following sentence at p.8 l.7: "The DEM full resolution is the images mean ground resolution, which is estimated from the average flying height. This average flying height is estimated from mean flight altitude and the average altitude of SIFT points." Adding this sentence implies to add the following words at the beggining of (p.12 l.1) (Section 3.2 3D Model): "As explained above, Micmac determines

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automatically the optimal..."

REVIEWER p8, l8 bundle ?

AUTHORS RESPONSE: The wording "bundle adjustment" cannot be separated. This expression is used in both computer vision and photogrammetric communities to describe the step of simultaneous estimation of internal (e.g. lens calibration) and external parameters through the minimisation of 3D reprojection error of all light rays linking ground features and their image position in each image ; the word "bundle" in the expression "bundle adjustment" comes from this bundle of light rays.

REVIEWER p8, the micmac process... "Two points" please find a text more appropriate. + pbs in the numerotation of the lines of p8.

AUTHORS RESPONSE: We propose to use the word "item" instead of "point". Numerotation problems will be double checked in the revised version of the manuscript. They may come from the latex compilation and may not be tunable by the authors.

REVIEWER p9, table 2 micmac pipeline command name Tapas is there is a way not to load all the SIFT points calculated in all images ? in order to remove the cited bottle neck in the data processing ? develop a bit the comment of the table.

AUTHORS RESPONSE: This bottleneck is quite classical in SfM (as noticed also, for instance, by Smith et al 2015). It is in fact the intrinsic drawback of SfM methods, which maximize the use of image information and then in turn, have to find a way to manage with such large datasets. Some ways to address this bottlneck exist, though, starting with algorithms to decimate the set of SIFT points in order to keep the one which give the more information. We propose to add the following sentences to precise this: "As pointed by other authors (e.g. Smith et al. 2015), this creates a bottleneck in resource capacity, especially in consumer-grade computers. Several workarounds are developped, starting from increasing computer power and using computer cluster, to algorithmic developments. These developments can have different directions : trying

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to merge results of computations done by chunks, decimating the set of SIFT points so that less memory would be necessary, for instance." Table caption is proposed to be developed as follows: "Description of the commands used sequentially in the typical Micmac pipeline, from images to the DEM and orthophotography. The table describes each operation in a few words, gives the name of the Micmac command and then details its main options and potential limitations" Finally in Table 2, details for the Tapas command would be completed by the following: "model of lens distorsion ; memory necessary to load the whole set of SIFT points calculated in all images, possible workarounds with RedTieP/OriRedTieP"

REVIEWER p9, l21 : precise what you call "...a rather poor 3D structure."

AUTHORS RESPONSE: We propose to insert the following sentence to explain these words: "Indeed when terrain height variability is low relatively to imaging distance a strong correlation between sensor altitude and focal length appears."

REVIEWER p10, l3: differnces between original topography and smoothed topography are computed. Plenty of such had already been done since the 19th century in geography see Summit level surfaces processing in order to calculate erosion balance and son on... please cite a bit former/previous authors.

AUTHORS RESPONSE: As already said above, we agree with the remark of the reviewer. Such information has to be given in the introduction. As said above, we propose to rewrite the "Goal" section in order to precise how our work contibutes to the litterature and how it is positioned relatively to the existing work. Moreover, reviewer 1 asked for more information about this section. We hence propose to rewrite section 2.5 (see proposed revised 2.5 section in the supplementary material file) and to add a new figure : a flowchart which describes the way gullies mapping is done (see Fig. 3 of this document). The proposed caption for this new figure is: "Flowchart of the method used to map gullies from the kite DEM. Letters associated with each step are referenced in the text describing the method in section 2.5"

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REVIEWER p.11 what is the total load of the rig ?

AUTHORS RESPONSE: The total load of the rig, comprising the camera and its lens, the GPS logger and the automatic triggering device is roughly 500g. We propose to add this information at two locations in the manuscript : in the material and methods section were simulations are explained and in the caption of the figure p11. Proposed added text at p.6 l.16:

"For all simulation, the total load of the rig was 500g, which is the actual load of the rig we used (Figure 2)."

Proposed modified caption of submitted Figure 4 p.11:

"Comparison of the shape of 300m lines (black bold) with "ideal" (thin grey) ones on a kite flown under different wind conditions. Total load of the rig (Figure 2 - right) for the simulation is 500g. "Ideal" lines are modelled as weightless and causing no drag. Left: Dyneema(c) line (0.1g/m). Right: polyester line (1g/m)."

REVIEWER p11.l16: how did you choose the strenght 90kg is it calculated ?

AUTHORS RESPONSE: Strength line must be roughly one order of magnitude superior to the theoretical drag of the kite. The strength line has also to be chosen according to the strength of existing lines. We propose to precise this in the text by changing (p11 l16) sentence as follows: "Considering that the drag of the kites is always less than twenty kilograms even in strong winds (otherwise a smaller kite - with lower drag - is used) and that rouglhy one order of magnitude is requested as safety margin, we chose the closest available line strength which was 90kg."

REVIEWER p.12, fig. 6: is it 4 or 6m2 delta kite ? what is this surface ? not cited in the texte of the ms...

AUTHORS RESPONSE: The "6m2" number is a mistake done when creating the figure. We only had 4m2 and 10m2 delta kites. We corrected this (see Fig. 4 of this document).

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REVIEWER p13: Fig. 7 please increase the contrast by lowering the sun light elevation. it will be clearer. develop the legend of the figure

AUTHORS RESPONSE: We agree with the reviewer that contrast has to be improved on the main view. In the submitted figure, shadowing was computed as the part of visible sky for each pixel, which is a good shadowing algorithm for highlighting local features, but a bad algorithm for the whole test site. We hence propose to use an algorithm with classical shading for the main view. The proposed revised figure is the Fig. 5 of this document and the proposed revised caption is the following : "Shaded views of the computed DEM over the Kamech test site. The main view is a classical shading of the DEM computed with a unique illumination source located east. The three zoomed views are shaded view computed as the portion of visible sky at each point. This type of shading highlights local features such as steep slopes and hard cuts: (a) shows a gully head ; (b) shows some cultivated plots with the plot borders easily visible and a gully head downstream the plots ; (c) shows erosion which grows upstream - regressive erosion - in the main thalweg"

REVIEWER Table 3: please precise error in planimetric and vertical directions

AUTHORS RESPONSE: Error was only computed in vertical direction. Our dataset does not allow us to compute error in planimetric direction. We hence propose to : 1. precise it in the 3.2 section (p.8 l.10) by replacing "to compute estimation error" by "to compute altimetric error statistics" 2. precise it in the table caption by replacing the current caption by : "DEM altimetric error statistics"

REVIEWER p13, l3: Plot limits form humps due to ... please precise not clear enough.

AUTHORS RESPONSE: These features are the signature of differential tillage erosion. We propose to explain this by adding the following lines: "Indeed, tillage erosion only affects the cultivated part of the plots ; none of two neighbouring farmers cultivate the limit between two plots. Consequently, limits between two adjacent plots are not exposed to tillage erosion and form humps which are visible in the DEM."

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REVIEWER p13, l6-7. would allow the production of numerous thematic maps... It is already the case since several years...

AUTHORS RESPONSE: We agree with the reviewer that this sentence does not bring new scientific material so we propose to remove it.

REVIEWER Page 14, l13: Please develop a bit the application. precise what have a regressive dynamic and spresad into cultivated plots means...

AUTHORS RESPONSE: We propose to rewrite and replace the last two lines of this paragraph (p.14 l.11-13) by the following text (figure numbering may change in the revised manuscript ; reference here is with respect to the figure numbering of the first manuscript): "DEM inspection shows that the test site comprises different kind of gullies. Some gullies (in the area showed on subfigure 7-a) remain contained in greater ravines, which means that erosion has occurred at least at two distinct times; the inner gully is currently active, while the greater ravine, with its smooth shape, is the relict of ancient erosion. Some gully heads are located uphill of the larger ravines described here above, which denotes regressive erosion in the modern times (in the area showed on subfigure 7-b). Downhill the same gully, one can see that the gully bottom ends in a cultivated field, which is the main concern of current erosion for farmers. Finally, subfigure 7-c shows a step-pool feature in the main channel with vertical overhang, which indicates that erosion is also active in this part of the landscape.

REVIEWER p15, l13 Geosciences and not geosciences

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

REVIEWER p15, l22: kites, ? to be modified...

AUTHORS RESPONSE: Many thanks ; a reference to Marzolff, I. and Poesen, J. (2009), not correctly spelled in the latex code, leaded to this "?" mark and was missed by both the authors and the english corrector. Corrected/added reference : Marzolff, I. and Poesen, J. (2009), The potential of 3D gully monitoring with GIS using high-

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resolution aerial photography and a digital photogrammetry system, Geomorphology, 111, 48–60.

REVIEWER p15 these figures are in par with other works (translation pbs ?)

AUTHORS RESPONSE: We propose to replace this part of the sentence by: "These figures are consistent with the ones of other works"

REVIEWER p17, 5 Conclusions p17, l16 frugal ?

AUTHORS RESPONSE: We wanted to highlight the fact that the proposed work has the advantage to provide accurate DEMs using inexpensive material. We think important to use the "frugal innovation" term because most work using inexpensive material improperly use the term "low cost", which implies lower service or lower quality. In that sense, our approach follows the main principles of frugal innovation. We may quote the "frugal innovation" expression if requested for making the sentence more clear.

REVIEWER p17, l 25 simulations ?precise

AUTHORS RESPONSE: We propose to rewrite this as follows : "This hypothesis - admittedly critical - was validated both with kite flight experimentations within different conditions and by numerical simulations of kite behaviour with different parameters.

REVIEWER p.17, l5: "These results open a new window => these results develops in the fields...

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

REVIEWER p.18, l6: and BETTER understand erosion processes...

AUTHORS RESPONSE: This will be corrected in the revised version of the manuscript

REVIEWER Moreover It is needed to precisely check the reference list... Agisoft 2014 missing in the ref list. Verify also that all the listed references are cited in the text...

AUTHORS RESPONSE: We propose to make reference to AgiSoft software without

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year so that this mention would not be confounded with academic bibliographic references. We corrected the "?" mark which was linked to a misspelled latex code. In the revised manuscript, all references will be managed through latex code so that all listed references in the text would appear in the reference list.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-60/nhess-2017-60-AC2-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-60, 2017.

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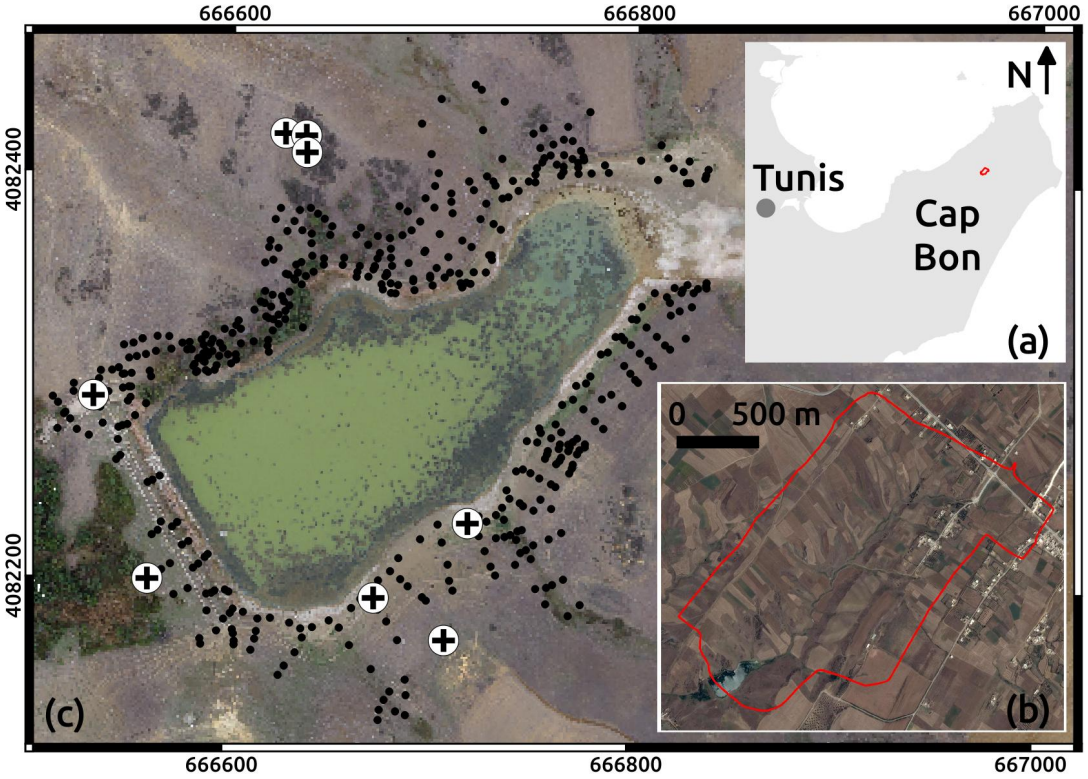

Fig. 1. Location of the Kamech test site and available ground truth data. (a) Location of the Cap Bon peninsula, in the north east of Tunisia; Kamech test site is marked in red. (b) close-up on the Kamech wat

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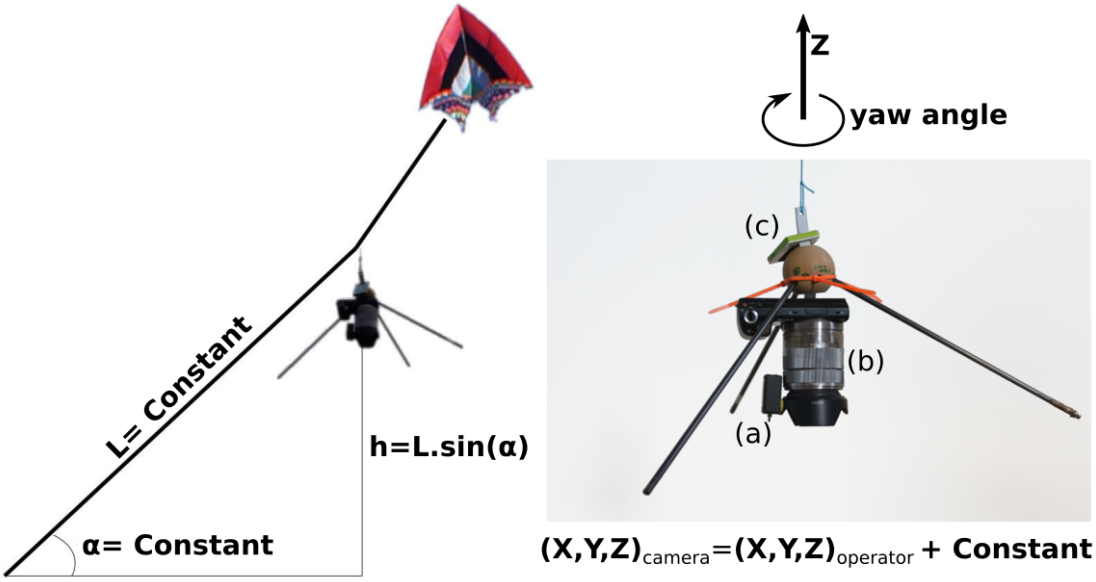

Fig. 2. Left: schematic principle of acquiring images by kite with a steady flight angle. Right: Tripod with camera: (a) intervallometer ; (b) camera ; (c) GPS. The yaw angle is the angle around the Z axis.

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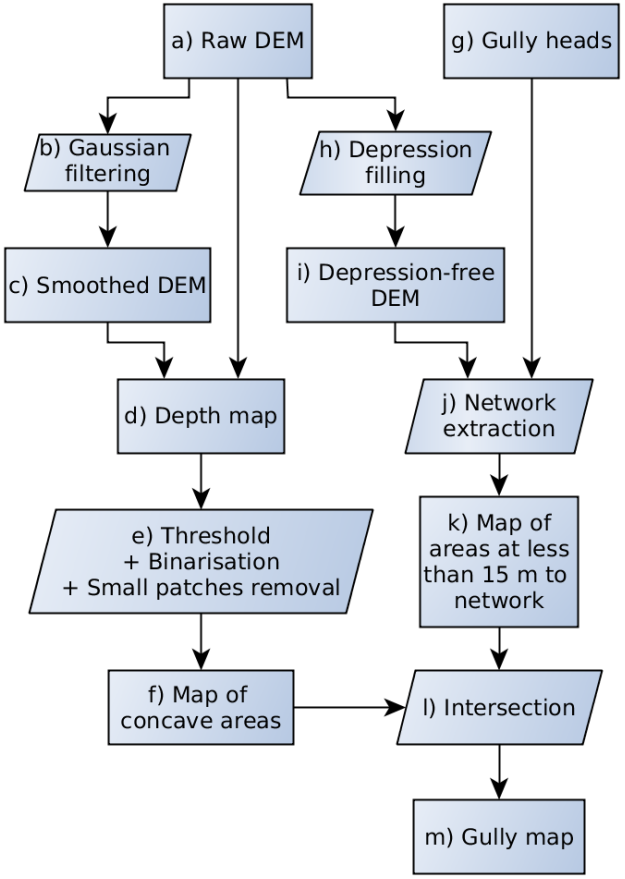

Fig. 3. Flowchart of the method used to map gullies from the kite DEM. Letters associated with each step are referenced in the text describing the method in section 2.5

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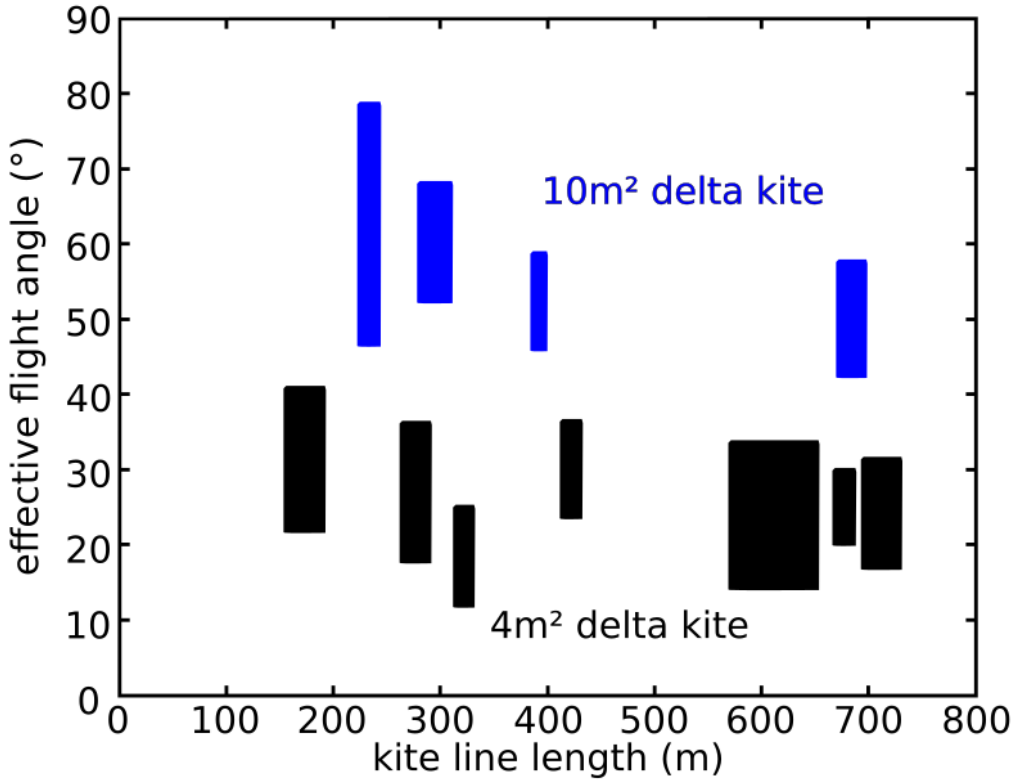

Fig. 4. Observed flight angle for the two kites and various conditions of wind speed and line length.

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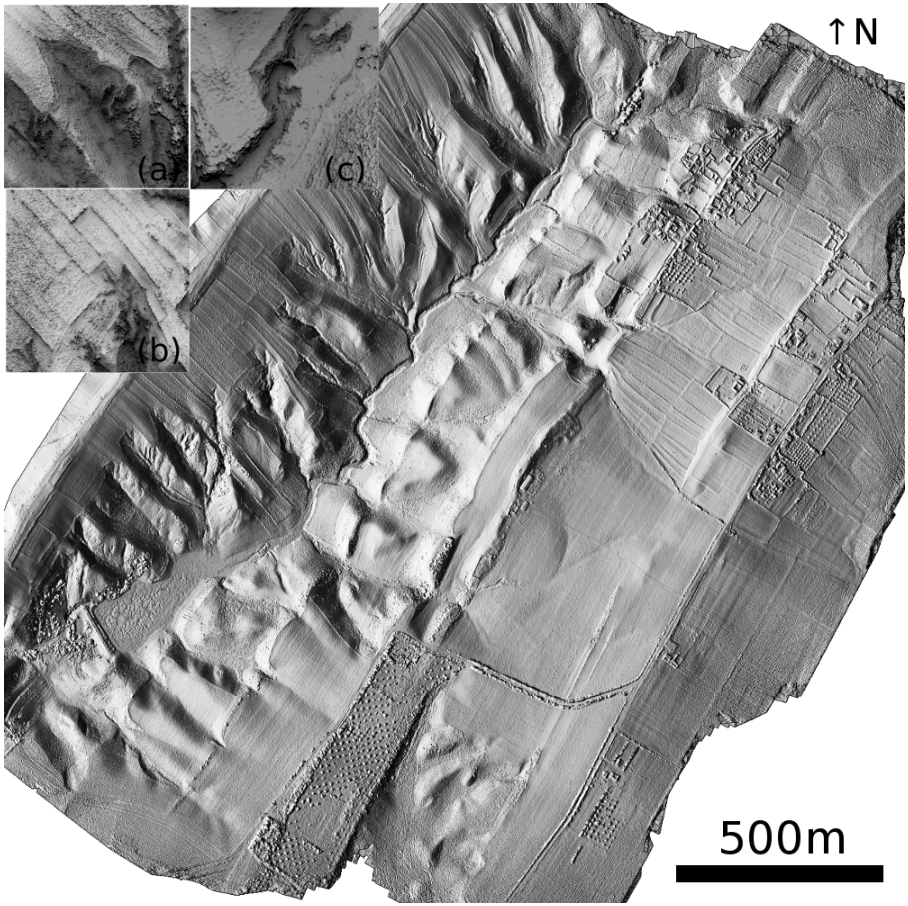

Fig. 5. Shaded views of the computed DEM over the Kamech test site. The main view is a classical shading of the DEM computed with a unique illumination source located east. The three zoomed views are shaded v

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