Dear Professor Nunzio Romano,

We thank you and the referee #4 for your detailed comments on our manuscript. We addressed all comments as detailed below in the paragraphs beginning with RESPONSE, and submit the revised manuscript. As you have been informed, the revision was delayed because of additional validation measurements which had to be taken and a complete re-analysis of the images with correction for white balance implemented. We hope that with this the concerns of all reviewers will have been removed.

Best Regards,

Katarina Džubáková, Peter Molnar, Konrad Schindler, and Milan Trizna

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Editor Decision: Reconsider after major revisions (09 Aug 2014) by Prof. Nunzio Romano

Comments to the Author:

Dear Authors,

While you have well addressed most of the previous referee's comments, as also acknowledged by one referees, there are still some parts of the manuscript deserving attention prior a final acceptance is made. For example, some of your replies should be inserted into the new version, as it is the case of the three bullet points about the novelty of the work on the first paragraph of your "Joint Response to Anonymous Referees 1-3".

Overall, and more importantly in order to strengthen your work, I share one big concern of one of the additional referee about the fact that the validation issue of your proposed method is definitely not addressed properly. In your responses, you have just replied that in your study validation is a difficult process and that the necessary resources to carry out that task are unavailable at present. However, some sort of validation of your results is practicable, I guess, and required in order that confirm that any changes detected using these methods correspond to changes in the natural system and not because of external influences on the images such as soil reflectivity or the quality of the ambient light.

I release the manuscript for your consideration of the important points raised by Anonymous Referee #4. Please, provide a point-to-point response. Should you disagree with some comments, please clearly explain why.

RESPONSE:

1) We have included the summary statements about the novelty of the work from the first response letter at the end of the Introduction Chapter. We have also expanded the discussion of the different options for remote monitoring of riparian vegetation and the discussion of potential enhancing and destructing flood effects on vegetation from the response document in the Discussion Chapter.

2) We are aware that validation was a weak point of our dataset and analysis. To fix this we have taken two steps. First, we have conducted ground-truthing measurements of spectral reflectance at 18 sites on the main gravel bar in September 2014. From these we have computed a correlation between image NDVI and "true" NDVI and the result is presented in a new figure 4. Given the difficulty to locate the footprint of the point spectral measurement exactly in the image, we are satisfied with the result. Second, we extracted a series of over 40 14-day long low-flow periods for which we calculated the standard deviation of the change in vegetation index and compared to the five large floods. This is a validation in that it gives us a reference range of variability that we may expect in VIs under low flow conditions. The result is that we do find changes much larger than the reference under normal flow conditions, which confirms that our data are measuring meaningful and measurable effects of floods on the floodplain vegetation. This is now presented in a new figure 5.

3) In this context we also recomputed all indexes for images which were corrected to a uniform white balance, in line with a concern of referee 4 that ambient light may be affecting our results. Although the results have not changed we will keep this post-processing step in all out future analyses, because it indeed is a necessary step to ensure that changes are not due to an arbitrary selection of light conditions.

Referee #4

The repeat multi-spectral terrestrial photography method presented by the authors appears to be generally sound, as is their use of previously established vegetation indices. The use of these cheap and low maintenance methods for quantifying geomorphic change and vegetation response to floods is a significant contribution to the field. I have significant reservations, however, about the quality of the results obtained from the analysis of the photographs, and would like to see validation tests as well as error analysis that confirm the reliability of the method before it is used to draw conclusions about the behavior of a complex and dynamic natural system.

Many of the issues raised here and by previous reviewers could be addressed by more clearly re-framing the manuscript as a methods paper. The current goals of the study, as stated at the end of section 1, are to detect unknown changes in a natural system. I hold, however, that any results are questionable unless the method is shown to accurately detect what it is supposed to be detecting. The authors address the previous reviewers' requests for validation in their reply and state that this is a difficult process and that the necessary resources are unavailable. I acknowledge this reality but insist on the importance of some sort of validation of the results that confirm that any changes detected through these methods correspond to changes in the natural system and not external influences on the images such as soil reflectivity or the quality of ambient light. I suggest, at a minimum, that the method should be shown to meet two criteria:

(1) It detects no change during the flood study periods in areas near the channel that were not affected by the flow. This is currently not the case: figure 6 shows significant change throughout the Secondary Bar and central part of the Main Bar for pre-2011 floods, even when it is stated in lines 120-122 that these were not submerged during those events.

RESPONSE: We agree that validation is a necessary step and we explain the two steps we have taken to ensure a first order validation of the data in the response to the editor above. Here we would like to address the two criteria suggested by the referee. The first criterion is not directly applicable, i.e. a flood event influences the hydrological conditions of the whole floodplain, in particular the areas close to the channel, by locally raising the groundwater level even if no overbank inundation occurs. Access to subsurface water and groundwater, can effectively cause a change in biological processes of non-submerged vegetation, which the vegetation index should capture. Therefore, we are of the opinion that the assumption of no reaction of the non-submerged vegetation does not necessarily correspond to reality and so is not a good validation criterion. We have also observed that plants on banks close to the river can have their roots submerged by flow for extended periods of time without overbank flow, which also directly impacts their growth. However the second criterion is applicable and we did test it:

(2) It detects no change in the vegetation on the active floodplain for randomly selected periods (of the same length as the flood study periods) when no high flows occurred. This would also provide a measure of the error in the method.

RESPONSE: For the following analysis we used all available periods of 14 days when the discharge did not exceed Q_1 (flow with return period 1 year), i.e. there was no overbank discharge. For each period we computed VI^{bf} and VI^{pf} using the same method as explained in the paper. The VI^{bf} and VI^{pf} matrices were subtracted and a standard deviation of the vegetation change delVI was computed for a selection of pixels representing vegetation cover (NDVI(2008) > 0.5). Altogether 41 periods low-flow periods and the 5 floods were then compared. In the new figure 5 we show the computed values of the standard deviation of delVI as a function of the time of occurrence. The results put the results of the presented paper in a broader perspective, namely, vegetation reaction to large floods was higher than that for the low-flow periods. Most importantly, vegetation reacted most strongly locally (highest standard deviation of delVI) to the largest flood in July 2011 with widespread occurrence of scouring. This new analysis presents a range of expected variability in vegetation indexes which can be used to assess where local changes are excessive and gives a validation of the sensitivity of the method and data to large floods.

I share another reviewer's concern about the meaning of "vegetation enhancement", and whether any significant biological changes could be visible over such a short timescale and distinguishable from, for example, the removal of litter changing the color of the background.

RESPONSE: Provided that the vegetation indices are sensitive to vegetation photosynthetic activity, the recorded immediate vegetation enhancement in terms of increased photosynthesis is possible. Based on our data it is difficult to quantify the added soil reflectance due to the removal of litter, the recorded results are more likely a combination of both factors. Their differentiation needs further research. We are for instance planning plant scale measurements of stomatal conductance of salix following large floods on different locations of the gravel bar to answer precisely this question.

The manuscript is well organized and the language is generally good, although the wording of sections 1 and 2 can occasionally be confusing. The text is sometimes vague and could be significantly condensed.

RESPONSE: Corrected

The figures are clear and well designed. The text and figures are, however, not fully integrated, leading to the figures sometimes not being fully explained by the text that refers to them.

RESPONSE: We have tried to integrate the explanations of the figures better into the text

The captions need to more thoroughly describe the content of the figures. This is particularly important for figures 5 and 6.

RESPONSE: Corrected

There is a lot of well-written explanations in the reply to reviewers that could be used in the manuscript. For example, the three bullet points about the novelty of the work on the first paragraph.

RESPONSE: We have done that. Please see response to the Editor.

Line-specific comments:

105+: An understanding of what the different indices characterize and what the values mean seems to be assumed further on in the manuscript. Significant more detail in this section is necessary for readers to follow the text later on.

RESPONSE: In the new revised version we stress the idea that based on our data we cannot say what the indices in riverine environment are able to identify and that this should become a subject for further research. That is also a reason why in our work we use the indices as an indicator of general vegetation vigor, which we understand as a combination of vegetation greenness in terms of leaf pigments intensity (and with it related photosynthetic activity) and leaf area.

112-116: Grammar: Two sentence fragments that should be separate sentences.

RESPONSE: Corrected

117-119: It's clear that increased sensitivity refers to an increase in the error in the data (more sensitive = more error), but sensitivity is also used to refer to the ability to detect a signal (more sensitive = less error). Use "are negatively affected" or something similar.

RESPONSE: Corrected

120: What does "which is specific to riparian systems" refer to? Are these VIs not suitable for riparian systems because their vegetation tends to be sparse, and the optical properties of the soil introduce error to the data? (Isn't this a problem when trying to detect vegetation removal, since the percentage of bare ground will change?)

RESPONSE: We decided to reduce the list of vegetation indices to the minimum, thus this part have been omitted. The problematic of the application of broadband vegetation indices within riverine environment was added to the text.

121-122: Grammar: Which methods were “modified”? Modified RVI and NDVI to develop multiple SAVIs? Problems with verb-object relationships in paragraph.

RESPONSE: Reformulated

125- 126: Why were these specific methods selected? What do their values represent in nature?

RESPONSE: Answered in the question in the first sentence of the paragraph

139 (and elsewhere): Grammar: Should use a comma before “which”, no comma before “that” (“… of a gravel bar, which are…” OR “… of a gravel bar that are…”)

RESPONSE: Corrected

170: Is “Bignasco” a reference to a specific location? Specify “at the village of Bignasco” or “at the XXX gage near the village of Bignasco”. Later on give the full reference to the gage, but should do it at the first reference.

RESPONSE: Reformulated

176: Grammar: “on the average” -> “on average”

RESPONSE: Corrected

179-190: How were the edges of the zones defined?

RESPONSE: Added

216: The *reported* peak flows are lower estimates

RESPONSE: Added

224-225: Said in 222 that SB and much of MB were only submerged in 2011, but then said that a discharge defined as a flood inundates the majority of the riparian zone.

RESPONSE: Corrected

266: The angle is given in the manuscript as 25 degrees, in the replies to reviewers as 38 degrees.

RESPONSE: The value of the 25 degrees is the correct value. We are sorry for the mistake.

284: It seems like not fixing the white balance and not having a white reference card could introduce unwanted variability to the relative intensities of RGB. Auto white balance can cause problems if the images are mostly one color - here, green. If this is combined with changes in the color temperature of ambient light (which can range from 5000 K on a clear sunny day to 10000 K on an overcast day), it seems that the DNs might not be reliably constant on different days (and therefore “change” would be detected)

RESPONSE: Thank you for your contribution to this point. Indeed the white balance potentially does have an effect on the image brightness. For this reason we redid all analyses for images which were re-processed in the RAW format by fixing the white balance to a daylight temperature (T=5,500K). The revised version of the manuscript has the new analysis. We agree that this normalization of image brightness to the same standard should be done and is now a standard step in our analysis in the post-processing. The most significant difference in results is in the analysis of the index disagreement, where SAVI and GSAVI proved to have different sensitivity using corrected images in comparison to our former results. The other analyses were enough robust to maintain the main message presented within the article.

319-329: Is the location of the five fluvial features reliably stable over time? What are the values reported as image distortion referring to? What's the minimal area that can be studied in the image? The trees in figure 2 look to be less than 2x2m in footprint.

RESPONSE: The fluvial features correspond to the easily identifiable tree individuals. Given the short time period of interest, we are convinced that despite tree growth, the shape and position of the trees has not changed. The orthorectification points were defined for one image and then the same values were uniformly applied on set of already registered images. As consequence, the image orthorectification caused distortion of vegetation individuals by 1-2 pixels, but each tree was distorted on each image uniformly. Hence, orthorectification did not cause any significant additional problems in the registration of vegetation individuals. In the current version of the manuscript we try to clearly state that the images do not capture the herbaceous cover due to its sparse distribution (and therefore small footprint, Figure 2: first image on left). On the other hand, the tree individuals greater than 2 m are already well recognizable (image comparison with field data). We see an uncertainty in the identification of trees with height 1-2m. We do not consider this uncertainty to be crucial, because the small tree individuals tend to grow densely distributed thus their footprint increases. A very good example is small vegetation (size equivalent to the 1.5 m Salix individual in Figure 2) on the upstream part of the main bar that was eroded in 2011.

361: Is the threshold of 0.15 for defining vegetation a standard value? Do it account for variability in the nature of the vegetation affecting that threshold? (for example, bright green vs. dark green canopy)

RESPONSE: That was a typo, vegetation was identified with NDVI>0.5. According to our knowledge there isn't a generally recognized standard for vegetation cover delineation, especially applicable on this scale and with such complex environment. We chose the threshold delineation based on visual comparison with what was seen on the photos clearly as plants (e.g. Figure 8) , because it was the simplest and most effective method.

362: Specify in the text that the comparison reports a disagreement in direction before presenting the equation

RESPONSE: Elaborated

376: Is this a result of this study instead of an a priori assumption?

RESPONSE: Corrected

Section 4.1: Detailed knowledge of what each VI measures seems to be necessary to understand what their differences mean. As currently written, the immediate conclusion is that these comparisons are ranking the VIs from "best" to "worse", especially since the highest difference is over 30%. The aim of these comparisons is well stated in the reply to reviewers and should be expanded upon in the manuscript.

RESPONSE: Elaborated

417: Here, again, knowledge of the relationship between values of VIs and real-world characteristics of vegetation is implied. How is the vegetation composition known to be stable?

RESPONSE: The stability of vegetation composition in terms of vegetation cover area is verifiable by summing the number of pixels representing vegetation. Equal information is presented in the subplots of Figure 4. We elaborated the text.

428: The difference in the response of each VI category is only really visible in figure 5 for the Transition Zone.

RESPONSE: The tendency of more common vegetation enhancement for vegetation with higher VI^{bf} is also visible in main bar (2010, 2011) as well as in secondary bar (2011).

440: What the authors refer to as "enhancement" should be more thoroughly explained. It seems the timescales are too short to be observing an uptake in biological activity.

RESPONSE: Our understanding of vegetation response to floods is described in the introduction. Based on our data we cannot measure the specifics of the vegetation enhancement. It is likely a combination of increased respiration, photosynthetic activity, due to higher water availability in conjunction with climatic conditions.

Section 4.3: Widespread change is observed for the Secondary Bar and main area of the Main Bar for pre-2011 floods, even when those are stated as not having been submerged during those events. If this is not the reflection of a problem with the method, it must be very thoroughly explained in the manuscript.

RESPONSE: Floods are responsible for lateral seepage and increased groundwater table, in addition rainfall on the gravel bar surfaces increases local water availability. We included this information to the last paragraph in discussion.

461+: Much of this should go in the discussion, not results.

RESPONSE: Considered

481-510: Much of this should go in the conclusions, not results.

RESPONSE: We prefer to leave the section in the discussion part, because it relates to number of other papers.

531+: Far-reaching conclusions are drawn in this section about the effects of the floods on the vigor of plants and the distribution of species across the landscape. It seems that there is extensive knowledge about the specific characteristics of the plants on the study site that exceed the descriptions provided in section 2. If such detail about the effects of the floods on individual species can be known from this data, then this must be much more extensively supported in the manuscript.

RESPONSE: Reformulated

541: Increasing diversity in only 7 days seems unlikely.

RESPONSE: Reformulated. The vegetation composition in transitional zone is more diverse than in the rest of the floodplain units and has not changed in 7 days.

598: The data does not show a threshold effect. Only two magnitudes of floods were studied, so it's impossible to say that it's a threshold and not a gradual increase in response.

RESPONSE: Reformulated

The differences in response between the two floods in 2009, with the same recurrence interval, is unexplained.

RESPONSE: The differences between two floods in 2009 are stated in results (the last paragraph of 'Spatial distribution of vegetation response' section).

Comments on figures:

Fig 1: Add the catchment to the map or shrink the map. Increase the size of B1 and B2, identify the study reach in them. Red line around sectors is almost invisible when printed in black and white - change to solid black? Give lat-long grid shorter spacings so a second tick shows up.

RESPONSE: Corrected

Fig 2: Add letters to the images, identify the floodplain unit the pictures come from (MB,SB, or TZ).

RESPONSE: Corrected

Fig 3: Line for discharge seems to be missing. Lines for temperature and solar radiation are hard to differentiate. What is the box on the lowest plot? There are significant periods of abnormal solar radiation and relative humidity for flood study periods 1, 2, and 4 that suggest multiple cloudy days corresponding to several "before" or "after" pictures. Are the differences in the quality of ambient light between the periods before and after the floods really insignificant?

<u>RESPONSE:</u> The figure was corrected, color version of the figure added. To lower the impact of meteorological conditions we conducted image selection, thus the images of the worst quality were excluded from the consideration. More importantly, normalized vegetation indices (e.g. NDVI) were designed to lowed index dependency on meteorological conditions, therefore we expect the relatively small differences between the images should not significantly lower informative value of our results. However we are aware that further research needs to be done on this matter.

Fig. 5: What VIs are used to produce these plots? The small black count plots are not described in the caption. The extent of the dark boxes should be stated.

If different VI categories correspond to different types/ages/health of vegetation, isn't variability in their response expected just because they are morphologically different? For example, species A and B, corresponding to two different VI categories, could benefit equally from a flood, but A gets bushier and therefore more visible in the photographs while B has thin stems that grow quickly but are only barely more visible. Is the method sensitive enough to the characteristics of individual plants that this could be significant?

<u>RESPONSE:</u> Description of subplots added. We agree the method cannot recognize the differences of vegetation response due to the vegetation structure. Without further information about other contributing factors we cannot explain the change of vegetation vigor in relation to vegetation specifics. Added to discussion.

Fig 6: What VI is this showing? Add two columns to show the before and after pictures. Left: What's the threshold for transparency? Right: Should use a color other than red - placed next to the left column, seems to suggest that the color is representing the same information. The reply to reviewers places more importance on this figure and explains it more thoroughly than the manuscript does. The caption needs to be expanded.

<u>RESPONSE:</u> Index, threshold added. Red color was chosen intentionally to relate information of intensity of decreased vegetation vigor with number of indices indicating decreased vegetation vigor. We prefer to stay with the former version. Reference (median) images computed for period before and after floods (bit depth reduced) are attached in supplement.