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Interactive comment on "Monitoring of carbon dioxide fluxes in a subalpine grassland ecosystem of the Italian Alps using a multispectral sensor" *by* K. Sakowska et al.

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Dear Reviewer,

thank you for the evaluation of the manuscript and constructive comments. We addressed all the issues raised in the review. The reviewer will find below the responses to general and specific comments. We hope that, thanks to the comments and the suggestions, the scientific value of the article will be enhanced.

General comment:

The paper aimed to estimate gross primary production of subalpine grasslands re-

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motely. Using simple radiometer measuring reflectance in 16 spectral bands synchronously with CO2 fluxes, very valuable data set consists 5 years of observation has been collected. Authors tested two models based on vegetation indices, one of them including incident PAR, and two regression models. The results showed that in vegetation studied, a main factor affecting productivity is total chlorophyll content and, thus, primary production could be accurately estimated via remote detection of chlorophyll content. The results of this study are very interesting and convincing. I believe, more explicit presentation of the results greatly improve value of this paper.

Specific comments:

C1: Firstly, more explanation is required the fact that performance of model 1 (that does use any meteorological data, e.g., incident PAR) is better than model 2 where PAR was used. Recently many studies brought empirical evidence that using incident PAR in gross primary production (GPP) models, requiring meteorological data, does not increase accuracy of GPP estimation. Moreover, the models, which do not use any meteorological information and based only on remotely sensed data, perform better (e.g., Sims et al, 2008; RSE; Yang et al., 2013; GRL). Sakamoto et al., (2011; RSE) showed that the use of vegetation index alone allowed for accurate estimation of crop GPP up to the point where seasonal decrease of PAR became significant. Thus, seasonal change of PAR was found one of the factors affecting GPP. GPP is affected by incident PAR and the response of productivity to change in PAR relates to many factors such as vegetation physiological status and light climate inside the canopy, which affects absorbed PAR and LUE, among others. Therefore, the use of incident PAR in the model may introduce noise and unpredictable uncertainties (see figure below from Peng et al., 2013; RSE, showing it explicitly). As a result, it was suggested using calculated seasonal variation of PAR in the model (Gitelson et al., 2012; RSE). Thus, authors' conclusion that "the photosynthesis process is more efficient under diffuse compared to direct radiation, . . .the accuracy of GEPm estimation decreased after including incident PARm into the model" is only one factor in very complicated interaction

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GEP/PAR. I suggest to refer Sims et al., (2008; RSE) paper discussing this issue.

A1: We agree with both reviewers that the complex relationship between GEP and PAR should be further discussed in the paper.

For this reason, in the “Discussion” section we reworded the sentence in P14L19-P14L22 into:

“One of the reasons for this is that sunlight is used by plants more efficiently under cloudy than clear sky conditions due to a more uniform illumination of the canopy, and thus a smaller fraction of the canopy likely to be light saturated (Baldocchi and Amthor, 2001; Chen et al., 2009; Mercado et al., 2009).”

In the same section we added the following paragraph (P15L1):

“A recent study of Peng et al. (2013) confirmed that the use of PAR in the model can introduce noise and unpredictable uncertainties in GEP estimations. As suggested by these authors, the response of productivity to changes in PAR is quite complex and influenced by many variables such as vegetation physiological status, canopy structure and light distribution in the canopy. Some other authors also brought to light some important aspects related to the use of PAR. Sims et al. (2008) showed that the variation in PAR is a more relevant determinant of GEP over very short timescales, and appears to be important for diurnal trends. Gitelson et al. (2012) demonstrated that seasonal variation of PAR potential (defined as the maximal value of incident PAR that may occur when the concentrations of atmospheric gasses and aerosols are minimal) can be used to improve the performance of the models.”

Also, we reworded the sentence in P15L1-P15L4 into:

“Therefore, further analyses of the response of different vegetation types to various levels of diffuse radiation are required, and the hypothesis that the DI and PAR potential can improve the performance of the models including radiation as an input parameter needs to be verified.”

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And the sentence: “Also, the assessment of the influence of radiation quality on canopy reflectance should be further investigated.” (P15L4-P15L5) was removed.

C2: Secondly, the performance of the model 1 was very consistent among 4 years of observation (2008-2011); however, it was not a case for 2012. I do not see a problem that “the slopes of these linear relationships in 2011 and 2012 were significantly different from the general model”. Slope is not the only factor affecting relationship, there is also intercept. Relationship for 2011 was very close to five year line (Fig. 3 of the manuscript). What has to be addressed and explained is very different performance of the model in 2012. I suggest establishing GEP vs. VI relationship for four years (2008-2011) and explain discrepancy between this close relationship and that for 2012. The reason for this discrepancy is very important to understand; it brings crucial information about validity of the model.

A2: According to our observations, 2012 was a very particular year, with both high average precipitation rates and high average temperatures during the growing season (Figure 2 of the manuscript), which in this type of ecosystem led to optimal growing conditions and particularly green grassland with high green herbage ratio (GR) values (ratio between the green biomass and the total biomass) throughout the season. The Fig. 1 (of the Interactive comment) referring to the growing season of 2012 shows that the vegetation index values after the cut are the lowest (pattern dots). The same pattern is visible in the other years of observation (Figure 2 of the Interactive comment). In 2012, the values of NDVIred-edge right after the cut were higher compared to the NDVIred-edge values after the cut of the other years (Figure 4 in the manuscript); which means that also the fAPAR green values in 2012, right after the cut, were presumably higher than in the other years due to the favorable climatic conditions before the cut. On the contrary, in 2012 the GEPm values after the cut, were lower than in the other years for the same index values (Figure 4 in the manuscript), and this is expected to affect the slope and the intercept of the 2012 relationship. We presume that the reason for these low values of GEPm is that the grassland was undergoing stress right after

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the cut event. To check this hypothesis, we tested the precipitation pattern after the cut and we found that in 2012 no significant daily precipitation (>3mm) was recorded during the 15 days after the cut. For other years, no dry periods (>5 days without a daily precipitation > 3 mm) were recorded. Also, we calculated the Precipitation/Temperature ratio for the 15 days period after the cut. The P/T ratio in 2012 during this period was more than 10 times lower than in the other years. According to these results, we can confirm that the difference in the 2012 relationship is likely due to the drought event occurring right after the cut. Although the grass was greener compared to the other years, the GEPm values were lower than expected.

Following the suggestion of both reviewers we performed the validation of the best performing general models (model 1 and 4). Sections “Statistical analysis” (P9L21), “Results” (P13L5) and “Discussion” (P15L21) have been enhanced with the information about the validation procedure and results:

2.5 Statistical analysis:

“Additionally, a validation of the best performing general models (considering all 5 years of observations together) using training/validation splitting approach, in which one year at a time was excluded from the dataset, was conducted. The remaining 4 years subset was used as a training set and the excluded year as the validation set. The model was fitted (calibrated) against each training set and the resulting parameterization was used to predict the GEPm of the excluded year. Validation accuracy was evaluated in terms of RMSE.”

3 Results:

“Validation of model 1 based on NDVIred-edge showed that there was no relevant difference in the prediction accuracy among validation years (RMSE was varying between 3.12 and 3.85 μmolm-2 s-1, Figure 3 of the Interactive comment). The general model 4 validation results showed that considering the all 5 validated years RMSE was on average 3.26 μmolm-2s-1.”

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4 Discussion:

"The results of the validation of the general model 1 fed with NDVIred-edge showed that RMSE increased, compared to the non-validated general model 1 results, on average (averaging the values obtained from 5 validation years) from 3.41 to 3.48 μmolm$-$2s$-$1. The general model 4 validation results showed that RMSE increased, as regards to the non-validated general model 4 results, on average from 3.06 to 3.26 μmolm$-$2s$-$1. The highest decrease of the GEPm estimation accuracy was noted in the growing season of 2012 (Table 4 of the manuscript, Figure 3 of the Interactive comment), which was presumably caused by the unusual drought which occurred just after the cut event. The precipitation to temperature ratio for the period of 15 days after the cut in the growing season of 2012 was more than 10 times lower than in the other years which could have affected GEPm to the higher extend than VIs related to the canopy "greenness". As a consequence, models calibrated with the first four years of the dataset overestimated the GEPm measured in the second part of the growing season of 2012."

C3: Thirdly, in discussion authors should address limitations of the applied models. I am not sure that authors used right expression ("simultaneous estimates of "can be redundant") about necessity to assess light use efficiency in non-stressed ecosystems characterized by strong seasonal dynamics such as grasslands and croplands. But why "non-stressed" vegetation mentioned? Authors study natural vegetation that does stressed. LUE relates to electron transport that in turn relates to chlorophyll content. Thus, detecting chlorophyll content does help to take into account some aspects of plant physiological status but there are many other factors affecting plant status and, thus, assessing LUE is extremely important especially for natural stressed vegetation. Obvious lag between stress and decrease in chlorophyll content does affect accuracy of the model and it should be explicitly mentioned.

A3: We agree on the reviewer's observation highlighting the existing lag between stress and chlorophyll content, especially in shorter time observations, thus in the "Discussion" the limitation of our approach was mentioned (P15L28). Also, "Introduction" part (P4L8-P4L13) was slightly reworded.

1 Introduction:

"In non-stressed ecosystems characterized by strong seasonal dynamics such as some managed croplands, independent estimates of the light use efficiency may be unnecessary due to its relation with the chlorophyll content (Gitelson et al., 2012; Peng and Gitelson, 2012; Peng et al., 2011; Rossini et al., 2012; Wu et al., 2009), and this is particularly true for longer term estimates. Therefore most of the variations in plant productivity in such ecosystems should be reflected by changes in APAR (Lobell et al., 2002)."

4 Discussion:

"We must however emphasize that the possible limitation of the approach assuming a direct linear relationship between GEPm and VIs related to the "canopy greenness" is that variations of GEP due to the short term environmental stresses cannot be monitored by presented VIs, unless these stresses affect chlorophyll content."

C4: Forth, I suggest authors to select only figures those are really necessarily for clear an understandable presentation obtained results. These results are valuable and would be much better presented by selecting few self-explained figures.

A4: According to the reviewer comment, we think that the Figure 6, although it provides an overview of the time series of mean midday gross ecosystem production (GEPm) estimated from EC measurements and GEPm obtained with the various models, is not strictly necessary in the paper. Also, the paragraph referring to Fig. 6 (P13L5-P13L8) was removed from the manuscript.

C5: Finally, abstract does not seems to me very informative and conclusions requite thoughtful revision.

A5: Both, "Abstract" and "Conclusions" sections were reworded as follows:

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Abstract:

"The study investigates the potential of a commercially available system - based on a 16 bands multispectral sensor - for monitoring mean midday gross ecosystem production (GEPm) in a dynamic subalpine grassland ecosystem of the Italian Alps equipped with an eddy covariance flux tower. Reflectance observations and carbon fluxes were collected for five consecutive years, characterized by different climatic conditions. Different models based on linear regression (vegetation indices approach) and on multiple regression (reflectance approach) were tested to estimate GEPm from optical data. The overall performance of this relatively low-cost system was positive. Chlorophyll-related indices including the red-edge part of the spectrum in their formulation were the best predictors of GEPm, explaining most of its variability during the five consecutive years of observations. The use of the reflectance approach instead of the vegetation indices approach did not lead to considerably improved results in estimating GEPm: in fact, the adjusted R2 (adjR2) of the model based on linear regression - including all the 5 years - was 0.74, while the adjR2 for the multiple regression was 0.79. Integrating mean midday photosynthetically active radiation (PARm) into the model resulted in a general decrease in the accuracy of estimates, highlighting the complexity of the GEPm response to incident radiation. Significantly higher photosynthesis rates under diffuse as regards to direct radiation conditions were observed in our study. The best models were used to test the ability of optical data for GEPm gap-filling. Three gaps length scenarios (gaps of 1, 3 and 5 observation days) were simulated. The differences in the adjR2 performance of the gap-filling scenarios showed that the accuracy of the gap filling decreased slightly with the gap length. However, on average, the GEPm gaps were filled with the accuracy of 73% with model fed with NDVIred-edge, with the model using reflectance at 681, 720 and 781 nm and PARm data."

Conclusions:

"This study investigated the potential of a commercially available system - based on a 16 band multispectral sensor - for monitoring mean midday gross ecosystem production (GEPm) in a dynamic subalpine grassland ecosystem of the Italian Alps. Chlorophyll-related indices including the red-edge part of the spectrum in their formulation (such as NDVIred-edge and CIred-edge) were the best predictors of GEPm, and were able to explain most of its variability (adjR2 = 0.74 for NDVIred-edge, adjR2 = 0.73 for CIred-edge) during the five consecutive years of observations, characterized by different climatic conditions. Our results confirm the findings on the literature regarding the complexity of the response of ecosystem productivity to change in PAR. This response is influenced by many variables and in fact, in our study, the accuracy of GEPm estimation decreased after including incident PARm into the linear regression model and the photosynthesis process was shown to be more efficient under diffuse compared to direct radiation. More studies are needed in order to explore the utility of including DI and PAR potential in the models to improve their performance. Also, the use of the reflectance approach instead of the VIs approach did not lead to considerably improved results in estimating GEPm. Although a more detailed analysis of the full vegetation spectrum is desirable (for providing best performing algorithms and a solid basis for in-situ validation and up-scaling of optical models to the airborne and satellite platforms), the results indicate that such a relatively low-cost multispectral sensors can be adopted to provide a significant contribution in monitoring carbon dioxide fluxes and biophysical parameters in dynamic ecosystems, for improving gap-filling techniques and for further integration into more complex biogeochemical models."

References

Baldocchi, D. D. and Amthor, J. S.: Canopy Photosynthesis: History , Measurements, and Models, in Terrestrial Global Productivity:Past, Present and Future, edited by J. Roy, B. Saugier, and H. Mooney, pp. 9–31, Academic Press, San Diego., 2001.

Chen, J., Shen, M. and Kato, T.: Diurnal and seasonal variations in light-use efficiency in an alpine meadow ecosystem: causes and implications for remote sensing, J. Plant Ecol., 2(4), 173–185, doi:10.1093/jpe/rtp020, 2009.

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Gitelson, A. A., Peng, Y., Masek, J. G., Rundquist, D. C., Verma, S., Suyker, A., Baker, J. M., Hatfield, J. L. and Meyers, T.: Remote estimation of crop gross primary production with Landsat data, Remote Sens. Environ., 121, 404–414, doi:10.1016/j.rse.2012.02.017, 2012.

Lobell, D. B., Asner, G. P., Ortiz-Monasterio, J. I. and Benning, T. L.: Remote sensing of regional crop production in the Yaqui Valley, Mexico: estimates and uncertainties, Agric. Ecosyst. Environ., 1944, 1–16, 2002.

Mercado, L. M., Bellouin, N., Sitch, S., Boucher, O., Huntingford, C., Wild, M. and Cox, P. M.: Impact of changes in diffuse radiation on the global land carbon sink., Nature, 458, 1014–1017, doi:10.1038/nature07949, 2009.

Peng, Y. and Gitelson, A. A.: Remote estimation of gross primary productivity in soybean and maize based on total crop chlorophyll content, Remote Sens. Environ., 117, 440–448, doi:10.1016/j.rse.2011.10.021, 2012.

Peng, Y., Gitelson, A. A., Keydan, G., Rundquist, D. C. and Moses, W.: Remote estimation of gross primary production in maize and support for a new paradigm based on total crop chlorophyll content, Remote Sens. Environ., 115, 978–989, doi:10.1016/j.rse.2010.12.001, 2011.

Peng, Y., Gitelson, A. A. and Sakamoto, T.: Remote estimation of gross primary productivity in crops using MODIS 250 m data, Remote Sens. Environ., 128, 186–196, 2013.

Rossini, M., Cogliati, S., Meroni, M., Migliavacca, M., Galvagno, M., Busetto, L., Cremonese, E., Julitta, T., Siniscalco, C., Morra di Cella, U. and Colombo, R.: Remote sensing-based estimation of gross primary production in a subalpine grassland, Biogeosciences, 9, 2565–2584, doi:10.5194/bg-9-2565-2012, 2012.

Sims, D., Rahman, a, Cordova, V., Elmasri, B., Baldocchi, D., Bolstad, P., Flanagan, L., Goldstein, a, Hollinger, D. and Misson, L.: A new model of gross primary productivity for North American ecosystems based solely on the enhanced vegetation index and land surface temperature from MODIS, Remote Sens. Environ., 112(4), 1633–1646, doi:10.1016/j.rse.2007.08.004, 2008.

Wu, C., Niu, Z., Tang, Q., Huang, W., Rivard, B. and Feng, J.: Remote estimation of gross primary production in wheat using chlorophyll-related vegetation indices, Agric. For. Meteorol., 149, 1015–1021, doi:10.1016/j.agrformet.2008.12.007, 2009.

Additional note:

At this point authors would like to extend the "Acknowledgements" and thank Maurizo Bagnara, PhD student of Fondazione Edmund Mach, for help in R programming and John Gamon, Profesor from University of Alberta, for his valuable ideas.

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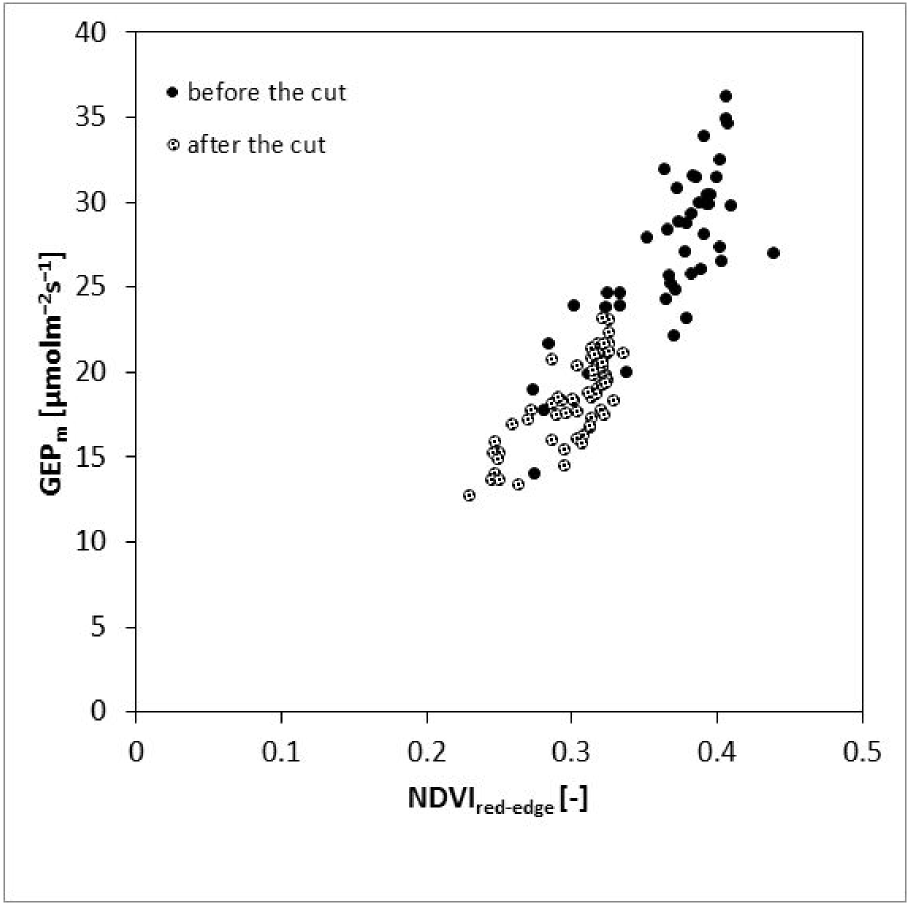

Fig. 1. Relationship between the NDVIred-edge and GEPm in the growing season of 2012.

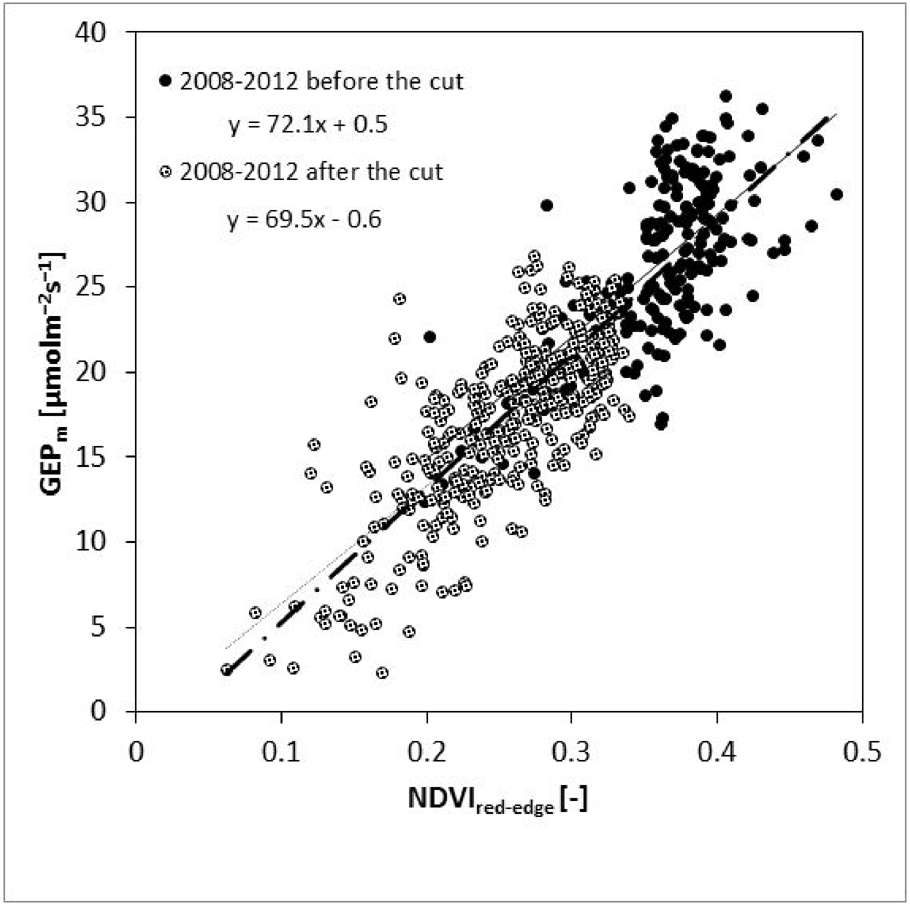

Fig. 2. Relationship between the NDVIred-edge and GEPm considering all the 5 years of observations.

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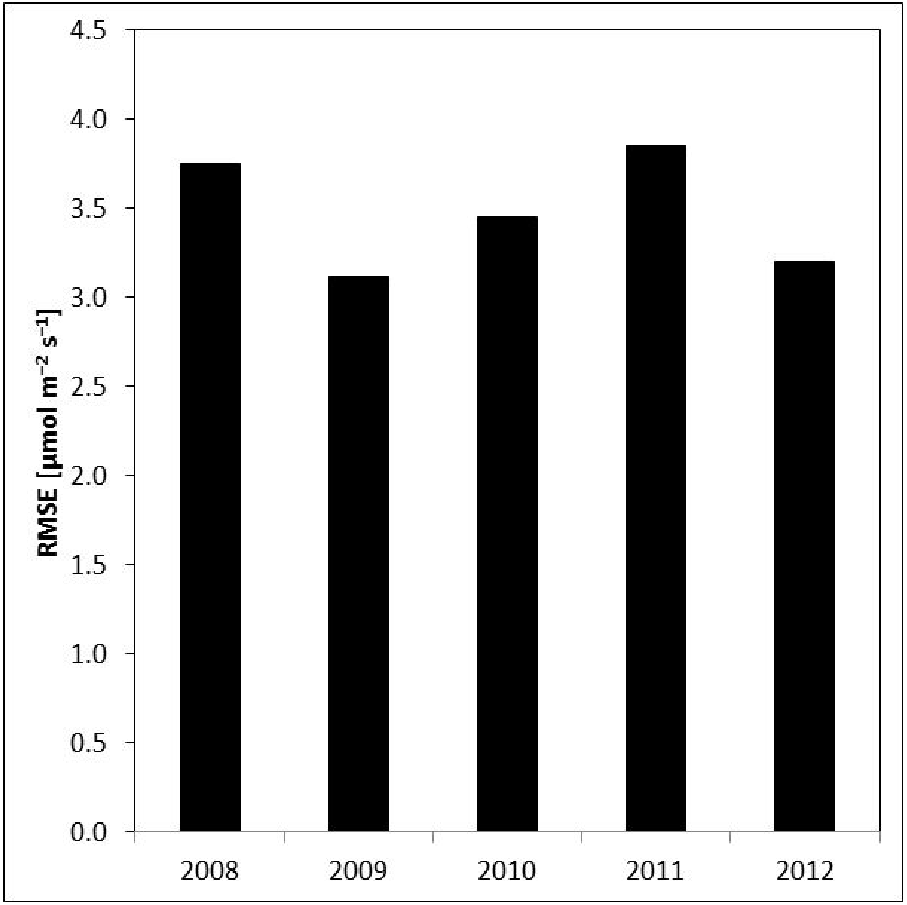

Fig. 3. Root mean square error (RMSE) of the validated models based on the NDVIred-edge.

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