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Biogeosciences Discussions

Interactive comment on "Analysis of vegetation and land cover dynamics in north-western Morocco during the last decade using MODIS NDVI time series data" *by* C. Höpfner and D. Scherer

C. Höpfner and D. Scherer

christian.hoepfner@klima.tu-berlin.de

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We thank the two anonymous referees for constructive questions and advice concerning our paper. In terms of language the revised manuscript will be checked by a native speaker to improve the readability.

We will proceed one by one to answer all other comments appropriately.

p. C656 #referee 1 "Each Table and Figure should be understood without having to resort to reading the text."

We will pay attention to this comment while preparing the revised manuscript.

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Interactive Discussion

Discussion Paper

p.C656 #referee 1 "Some Figures (3 and 9) do not have clearly explained X axis."

The two figures are corrected and will be implemented in the revised manuscript.

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p. C656 #referee 1 "Figures 13 and 14, giving both r and r2 is redundant. Instead, SE or SD information is more explanatory and should be given."

We inserted SD instead of r for the revised manuscript.

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p. C656 #referee 1 "Tables should be re-formatted."

This comment is unfortunately not clear to us. We are glad about every comment which helps to enhance our paper. If it is possible, please specify this comment.

C1211 #referee 2 "The problem statement needs to be enhanced to improve the originality of this work. After the problem statement, there is a short summary of the work. This part should be rewritten to formulate clearly the aim and objectives of this work. A clear definition of the aim and objectives at the end of the Introduction would help the readers a lot."

AND

C 1211 #referee 2 "Heading 1.2 is not reflecting the contents of the section. I would suggest to just remove headings 1.1 and 1.2, and just make Introduction a bit shorter by removing the lengthy description of vegetation indices."

We merged the two headings of introduction and added a new heading 'objectives' to help the reader following our work. The latter one is rewritten. In terms of removing the description of vegetation indices we are not sure which part #referee 2 means exactly.

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We work with NDVI data of MODIS sensor. Therefore we introduce NDVI shortly (1 sentence) and the two sensors AVHRR and MODIS which acquire time series data sets for NDVI based monitoring approaches. Emphasis is put on MODIS sensor and MODIS data (4 sentences). Thereafter we reference to studies working with MODIS time series data (6 sentences). There we summarise what others made using MODIS time series data in combination with ground truth data. This part has major emphasis due to the objectives of our study which deals with MODIS time series data in a region with very scarce ground truth data. Last we reference to studies dealing with phenology and phenologic parameters in general (2 sentences) and with MODIS NDVI time series data in particular (2 sentences) because our classification method applies phenologic parameters.

C 1211 #referee 2 "It does not appropriate to use GLC2000 and PFT as reference and then conclude that the produced classification is even better than the reference using as new reference visual interpretation of satellite images covering small subset of the area! It seems like PFT was discarded as reference because it only provided a 35.47% accuracy..."

This is not clearly described in the manuscript and leads to misunderstanding. We will consider this point in the revised manuscript. Our study shows a methodology to classify land cover using phenologic metrics. This classification is independent from other classification results like GLC2000 and PFT. To validate our own classification results we tried to acquire validated land cover information from local and national authorities and finally got a map for a small subset of the study region (Grand Casablanca as marked in fig. 11). This way we decided to validate our results in a first step visually with Landsat for the entire study region. We also included the global land cover products GLC2000 and PFT separately for visual validation to get an impression of the quality of our local classification. We never used them as reference but as comparison. Visual validation results (as described in the manuscript) were exemplarily pictured by

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using a subset around the city of Casablanca. In a second step we made a subset of our classification results and PFT classification to the extents of the validated map from local authorities. That way we could get a confusion matrix for our classification results and PFT classification with the local map as ground truth each. Results underline outcomes from visual validation: PFT classification overestimates cities and underestimates forests and vegetation apart of cropland. Higher accuracy and visual validation results lead to the conclusion that our classification fits better in the study region than PFT classification. We finally discarded PFT because of worse validation results.

C 1211 #referee 2 "Some conclusions (or intermediate conclusions) are obvious: cropland is obviously rain-fed if no irrigation systems are used; merging two classes which had high level of confusion of course will boost the overall classification accuracy. The latter is textbook knowledge."

In terms of overall classification accuracy of our classification and PFT classification we did not merged the two land cover types to boost the accuracy. The problem was to define appropriate training areas to run the validation correctly. To differ the city region into land cover type 'very sparsely vegetated' and land cover type 'sparsely vegetated', the old medina of Casablanca as very dense city quarter was used as ground truth polygon for land cover type 'very sparsely vegetated' and city quarters with less density were used as ground truth polygons for land cover type 'sparsely vegetated'. PFT classification just defines the class 'urban and built-up' without consideration of areas with lower or higher proportions of vegetation within the city. This way validation results of PFT must be obviously worse, because one class of PFT classification is validated with two classes of the official map. Additionally it was not clear to us, if the worse validation outcomes of PFT classification result from overestimation of cities or from definition of training areas as described above. Taking this into account, it was questionable to compare validation results of our classification and PFT classification.

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For this reason we repeated validation with merged classes for both classifications to eliminate the effect of the definition of training areas. Of course validation results are boosted this way, but finally we could conclude that overestimation of cities etc. still leads to worse validation results of PFT classification compared to validation results of our classification. We got so far statistic emphasis of confusion matrix underlining the results of previous made visual validation. In terms of precipitation we examine in one part of our study the relation of precipitation on vegetation. As explained we do not have ground truth knowledge. Hence, we do not know where croplands are irrigated and to which extent they are irrigated. We simply try to get as much as possible information from used data to get to know the widely unknown study region and to find an answer concerning irrigation of croplands. We try to show what is possible with MODIS data having high temporal but low spatial resolution. As example results show higher dependency of land cover type 'Low-productive vegetation' on precipitation than land cover type 'high-productive vegetation'. This way we can assume higher proportions of irrigated agricultural fields within land cover type 'High-productive vegetation'. Nevertheless we cannot verify irrigation directly. This way we have to consider croplands to be mainly rain-fed, if r2 (correlation with precipitation) is greater than 0.5. Concluding vice-versa that croplands are mainly irrigated because r2 is lower than 0.5 would be incorrect due to the definition of the coefficient of determination. This way it seems obvious that cropland is rain-fed if no irrigation system is used. But the aim of the conclusion within the manuscript is to work out information about irrigation or dependency on precipitation. We can conclude that vegetation in the study region is (of course) mainly rain-fed because of high dependency on precipitation. For croplands there is a high uncertainty concerning this topic due to scarce ground truth knowledge but anyway we can conclude from our study that croplands in the study region are (also !) mainly rain-fed. This was not obvious from this point of view before. We will clarify this two points in the revised manuscript.

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Interactive Comment

C 1211 #referee 2 "Perhaps I have not understood correctly, but how is it possible to show such a big difference of land cover changes every year, and then conclude that 1.6% only has actually changed "systematically". Clearly there was something wrong with the classification, possibly the decision to use fix classification thresholds throughout the years. Authors need to review the results or discuss the issue adequately"

The challenge was to find a good classification method even if there is scarce ground truth knowledge. We want to work out information about vegetation and land cover to differ between human-driven change, climate-driven change, vegetation trends and inter-annual ecosystem variability. To run classifications with variable thresholds throughout the years requires knowledge on inter-annual ecosystem variability in the study region. This knowledge was not available before. The simple adaptation of thresholds to precipitation sums is also questionable since we didn't had any idea of the precipitation-NDVI-relation before. This way we used fixed thresholds and regarded them as chance and challenge. Results of land cover classification catch the core of each land cover type as stably classified areas while the rest normally varies between two land cover types as described in the manuscript. On the one hand we get the possibility to extract information about land cover types and vegetation by examining the stably classified areas. On the other hand there is a big difference of land cover change every year to consider and discuss. In terms of land cover change detection the challenge is to delimit varying areas from areas with actual land cover change. Hence, we set different requirements for actual land cover changes as: "Within the nine years the area was classified in exactly two land cover types." "The area is classified as one land cover type 2-7 years in a row and as another land cover type 7-2 years in a row." "Areas with more than one land cover change will not be registered as actual land cover change." For instance the two different land cover types are A and B. A stably classified area of land cover type A will be classified 9 years as following: AAAAAAAAA

A varying area between A and B might be: AABABABBB or BABABABAB etc.

We consider patterns of

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AABBBBBBB (2+7), AAABBBBBB (3+6), AAAABBBBB (4+5), AAAAABBBB (5+4), AAAAAABBB (6+3), AAAAAAABB (7+2)

to have a sufficient likelihood to call it 'actual change'. For all others we consider the likelihood to low to conclude an actual land cover change. This way, the high difference of land cover changes every year contain also inter-annual ecosystem variability documenting e.g. dryer or wetter years. We will pay attention to illustrate this in a better way in the revised version.

C 1211 #referee 2 " Authors should explain how reservoirs were masked from SRTM data."

We added a short description concerning that topic to the revised manuscript.

C 1211 #referee 2 "The statement supporting the selection of the decision tree classifier should be enhanced with previously published literature."

AND

C 1212 #referee 2 "The statement that the decision tree classification method is more appropriate in the study area could not have been concluded from this work, as no comparison with other method was made. It should be removed or reformed."

We tried to apply also other methods as unsupervised ISODATA classifier or supervised maximum-likelihood classifier but results were not satisfying. In addition supervised classifiers need ground truth knowledge which was actually reduced to the administrative region of Grand Casablanca. That way we had a personal communication with Prof. Simonneaux working at the 'Centre d'Etudes Spatiales de la Biosphère (CESBIO)' in Toulouse. His team worked for a long period of time on this question in Morocco. He advised against traditional methods for land cover identification in Mo-

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rocco because they often fail in the Moroccan context due to high variety of crops, high heterogeneity of development and small parcels. His team developed a more robust method based on time series of NDVI. Hence, we stopped former attempts and focused on own methods using a decision tree. As advantage we didn't need ground truth knowledge to run it, but some thresholds from literature which are already documented.

C 1211 #referee 2 " What the authors refer as "systematic land cover change" is in fact an "actual land cover change", rather than an artefact from the methods used. I suggest renaming it accordingly."

This comment is very helpful. We renamed it to make the paper easier to understand and follow.

C 1212 #referee 2 "The statement that the other factors that could theoretically influence vegetation dynamics (except for rainfall) are less important, needs to be supported with analysis or relevant literature."

Fundamental agreement of science is that precipitation and vegetation response are linearly linked with a small delay in time. This relationship causes the sequence of vegetation periods in Morocco. Following the definition of the 'coefficient of determination' and linear regression approach, a result of e.g. r2 equal to 0.7 means that approximately 70% of the variation of NDVI can be explained by precipitation. Additionally it means also that approximately 30% of the variation of NDVI can be explained by other factors. It is an admissible consequence of the definition of the coefficient of determination concerning linear relationships.

C 1212 #referee 2 "Table 3: The land cover changes are between which years? Alto-

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gether, not more than 1% of the study region has changed. So, practically, there have been no changes..."

Table 3 documents summarised data of actual land cover changes for 2001-2009. We enhanced the description for the revised manuscript. The table documents all areas that can be considered to have changed land cover actually. Despite of the high inter-annual ecosystem variability it was possible to document an actual land cover change of 5981 pixel / 1.65% of the study region ashore / 373.8125 km2 as minimum level - an area which is nearly as big as Denver.

C 1212 #referee 2 "Figure 13: I'm surprised there is such a high correlation with practically horizontal fit line. It seems like an artefact, considering that there is tiny increase of NDVI with a wide variation of daily rainfall."

We scaled the axes homogenously to make it easier to compare the results. In fact, we could zoom the y-axis to turn up the regression line, but the small difference of NDVI will remain. Beside of an already small NDVI range from 0 to 1, the extent of differences of NDVI is heavily related to land cover type. Figures 9, 10 and 12 document the differences of intra-annual and inter-annual NDVI variability. Let us focus on figure 9 to explain: The different land cover classes have different intra-annual variability of NDVI. Land cover types 'very sparsely vegetated' and 'sparsely vegetated' have very small NDVI ranges and land cover type 'high-productive' has highest NDVI range. In other words the range between minimum NDVI and maximum NDVI of each land cover type is different. This is caused for instance by different percentage of vegetation, different density of plants and different duration of vegetation activity. If we correlate NDVI and precipitation, the differences of NDVI are of course within the range of NDVI values as shown in figure 9. In other words small differences of NDVI for land cover types 'very sparsely vegetated' and 'sparsely vegetated' are correct and no artefacts. It would be alarming, if the difference is higher. Practically, the nearly horizontal line is

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related to fig. 9. Focussing land cover type 'very sparsely vegetated' it is nevertheless interesting that even for a very small percentage of vegetation in a coarse grid a quite high correlation is detectable. And even if vegetation in these areas (mainly cities) is mainly rain-fed (r2>0.5), there must be also an influence of irrigation as for instance irrigation of trees alongside streets or irrigated flower pots at flat roofs.

C 1212 #referee 2 " There is a "t" missing from the first term of Equation 1."

Obviously. Thanks!

C 1212 #referee 2 "Authors should use hyphens (" ") when the describe class names in the text."

This will surely help the reader and will be included in the revised manuscript.

General comment: The paper is quite long as documented in authors comments. We will try to short it. Nevertheless the referee comments document also, that some topics are still to less explained. A revised manuscript will surely be enhanced but also longer. Thus we are thankful for every explicit suggestion which point out segments which can be reduced.

Interactive comment on Biogeosciences Discuss., 8, 3953, 2011.