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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on "Quantifying the effect of land use and land cover change on green water and blue water in northern part of China" *by* X. Liu et al.

X. Liu et al.

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Thank you very much for your comments. Abstract Comment # 1) The abstract contains unnecessary text that is rather burdening the document.

Answer # 1): In order to make the abstract concision, the following sentences for describing the modules of the distributed hydrological model were deleted from the abstract. "The direct evaporation from the intercepted water, potential canopy transpiration and potential soil evaporation were computed using a physically-based two-source potential evapotranspiration model, which would be regarded as input to the distributed hydrological model for the computation of actual evaportranspiration. Runoff generation was based on mixed runoff mechanisms of infiltration excess runoff and saturation excess runoff and the Muskingum-Cunge method was adopted for flow routing." The sentence "The result of runoff simulation showed that the saturation excess runoff generation was dominant in the catchment." for describing the minor conclusion was deleted too.

Comment #2) Line 18 19: The authors should indicate clearly by what percentage (significance does the change in land use and land cover have on evapotranspiration and runoff. This is useful in the abstract.

Answer # 2): The results showed that the change of land use and land cover had a significant influence on evapotranspiration and runoff. The land cover data showed that grass land and water body had decreased from 1980 through 1996 and forest land and crop land had increased. This change caused the vegetation interception evaporation and vegetation transpiration to increase, whereas the soil evaporation tended to decrease. Thus the green water increased by 0.95% but the blue water decreased by 8.71% during the period of 1964-1979 within the Laohahe Catchment.

Rest of document:

Comment: Page 2428 (line 4-7): Hydrological models are built based on experimental data. Even if models yield results faster and at less cost than experimental data, the importance of the latter cannot be overlooked. The results we get from models are not data but rather information which may or may not reflect the reality. It is useful for authors to take note of this.

Answer: Thank you very much for giving us this useful comment. We didn't want to overlook the importance of experimental data, because all modeling results should be examined by the experimental data. However, some limitations exist certainly in field experiments, for example the place of land cover change experiment was limited in some points, not over the catchment, and the field experiments need more instruments. These sentences in page 2428 line 4-7 were only to show some advantages of modeling studies, which could get general results based on precise input data and accurate model structure. In order to make the meanings clear, these sentences were revised as follows. "Based on precise input data and accurate model structure, hydrological models have the capability of addressing the impact of land use and land cover changes on hydrological processes."

Comment: Page 2429 (line5-6): What criteria did the authors use to choose the four periods? Is it merely a decadal time frame analysis or the authors were guided by change in spectral signatures obtained from satellite images?

Answer: It is a decadal time frame analysis. Due to the lack of land use and land cover data, some irrationality existed in the land use and land cover data distribution. For example, we don't have the land use and land cover data before 1980, thus the 1980 land use data were used to represent the land surface during the period of 1964-1979.

Comment: Figure 1 is not clear. The legend is not comprehensive. At least we would have expected an indication in the Figure which country the Laohahe Catchment is located.

Answer: Thank you very much for giving us this significant suggestion. The Figure 1 has been modified to show the study area clearly.

Comment: line 15-25: "grass land and crop land are dominant vegetations." These are land uses and not vegetation types. I don't understand what the authors mean by "direction of national development policies".

Answer: Line 15-20: The sentences "The main production approaches are agriculture and stock raising in the catchment, thus grass land and crop land are the dominant vegetations. The major driving force of land cover and land use change is increases in population and direction of national development polices. Since the foundation of China, there were four times large-scale reclamation in the catchment, however conversion of cropland to forest or grassland was also progressing at the same time." were

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changed into "Agriculture and stock raising are the main productive activities within the Laohahe Catchment, thus grassland and cropland are the dominant types of land use. The major driving force of land cover and land use change is population growth and local/national development policy. Since the foundation of China, there have been four times of large-scale reclamations in the catchment. However conversion of cropland to forestland or grassland was also progressing at the same time." The meaning of National development policy is that the policy is made by the government to promote the development of the country, according to the actual requirement of the people. For example, at the beginning of P. R. China foundation, due to the underdeveloped economy and lack of food in 1960's, the government encouraged the people to develop agriculture and enlarge the area of cropland to solve the starvation problem. In 1990's, the people found that the reclamation could cause many environmental isuues, such as water and soil erosion, inundation, environmental pollution. Thus the government made policies to protect the forest land and encourage the farmers to change the cropland into forestland or grassland. From above, we can see that the local/national development policy was an importance factor of land use and land cover change.

Comment: Where are the 19 rain gauging stations, 4 meteorological stations located in Figure 1?

Answer: The locations of 19 rain gauging stations and 4 meteorological stations have been described in the Figure 1.

Comment: Page 2430 Line 1:.annual precipitation occurs during the months from May through....this needs to be rephrased.

Answer: Thank you very much for giving us this useful suggestion. This sentence was rephrased into "Rainfall mainly concentrates in May-September, the amount of which accounts for the annual precipitation 88%."

Comment: Page 2430 Line 15-20: The authors seem to interchange the use of the term land cover and vegetation type. The authors need to be consistent and use the terms correctly. What is the relationship between the text in line 20 and Figure3?

Answer: Thank you very much for giving us this useful suggestion. The sentence in page 2430 line 19-20 was revised as follows: "The vegetation was primarily classified into 3 types, namely forest, grass and crop." The text in line 20 shows that the main vegetation types in Figure 3 are forest, grass and crop.

Comment: Page 2431: What are the units of the air temperature vapour pressure and wind speed? The same applies in other equations in the document.

Answer: Thank you very much for giving us this useful suggestion. The units of the air temperature vapour pressure and wind speed were added as follows. "The quantities Tobs, eobs, uobs are the air temperature (žC), air vapor pressure (kPa) and wind speed (ms-1) records at the meteorological station, respectively." The units of Eq.(7),(8),(10),(12),(13),(15)and (16) be added too. The details were seen in revised text.

Comment: Page 2432: This paper could have benefited from a comparison of the ET estimates derived from the two-source model with the freely available weekly actual ET data from the MODIS sensor and which has a spatial resolution of 1km.

Answer: I am ashamed that I don't know where and how to get the freely available weekly actual ET data from the MODIS sensor as you mentioned until now. In this study, the potential evpotranspiration (PET) was computed by the two-source potential evapotranspiration. The actual ET was simulated by the hybrid runoff model taking PET as the input data.The values of PET computed in this paper are in daily time scale, which can be compared with the freely available weekly actual ET data. The latter in weekly time scale are derived from the remotely sensed MODIS data by energy balance principle, not verified by water balance principle. However the actual ET values in this study are obtained from PET values based upon water balance principle by the hydrological model.

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Comment: Page 2433 (line19): What is the size of the grid for the distributed hydrological model? What is the benefit of using this model compared to other distributed hydrological models, e.g the SWAT model?

Answer: The size of the grid for the distributed hydrological model is 30 second, equivalent to one kilometer. The text in line 19 was revised as follows: "Potential evapotranspiration was used to drive a distributed hydrological model based on the grid of 30 second." The benefit of using this hydrological model can be summarized as follows: 1) The input data are easily prepared. The needed hydrometeorological data are obtained from rain gauging stations, hydrological stations and meteorological stations within and around the studied catchment, and the required remote sensing data, NDVI, DEM can be freely downloaded from the internet. 2) The potential evapotranspiration calculated by the two-source potential evapotranspiration model replaced the pan evaporation data as the input data, which can reveal the influence of vegetation types on potential evapotranspiration. 3) Both infiltration excess runoff mechanism and saturation excess runoff mechanism are taken into account by the hybrid runoff model, which is useful to describe the run off generation more reasonably in the semi-arid region. In the former study, the hybrid runoff model has been successfully applied in this studied catchment, which had better performance of runoff simulation. Thus this distributed hydrological model can be used to address the effect of land use and land cover change on hydrological cycle elements. As far as I know, the SWAT model are widely used to predict the long-term influence of human activities on the hydrological processes, sediment yield and chemic contamination transfer. However, the runoff generation mechanism in SWAT is only simple water balance. The hybrid runoff model together with two-source ET model in this study takes runoff generation mechanisms into more appropriate consideration than SWAT model in terms of the variability of topography and vegetation on runoff production.

Comment: Page 2434: This page and subsequent describes the runoff generation mechanism in the hybrid model. It is clear that soil characteristics govern this process

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and unfortunately there is no soil data or information for the study area indicated in the paper. How was runoff generated in the absence of this crucial data? Uncertainty analysis of the model used should be done.

Answer: Soil data weren't used in this study. As described in 3.2, the cores of the hybrid runoff model are spatial distribution curve of soil tension water storage capacity and spatial distribution curve of infiltration capacity (Figure 4). The parameters in the hybrid runoff model were calibrated by comparing the simulated runoff and the observed runoff, such as tension water capacity Wm, maximum infiltration rate f0, and static infiltration constant fc, etc. This paper didn't consider the spatial distribution of parameters, and the calibrated parameter values are the average parameter values in the drainage area. The relationship between model parameters and the information of land surface, such as root depth, soil type, elevation, and slope etc, will be set up in the future study. But root depth, soil type, elevation, slope, etc, have been applied to PET computation in this study. The runoff generation calculation was introduced as below. It is supposed that P is precipitation (subtracting evaporation at the same period of time) during the time interval of dt,W0 is the initial soil tension water storage in millimeter. Then runoff can be computed according to the relationship amongst P, Wm',W0'+Fmdt', and the intersection point of the two distribution curves introduced above. (1) There is a point of intersection between the two distribution curves if W0'+Fmdt' is smaller than Wm'. It is assumed that x represents the ordinate of that point of intersection. Run off computation could be made in the following three cases.

http://photos.i.cn.yahoo.com/liuxiaofanhhu/bd15e7/fc872b/

(2)There is no intersection point between the two distribution curves when W0'+ Fmdt' is larger than Wm'.Runoff computation may be made in the following three other cases. http://photos.i.cn.yahoo.com/liuxiaofanhhu/bd15e7/bd1222/

Where Rs is the surface runoff, Rg is the ground water runoff.

Besides the input data error, the model parameters equifinality problem, simplifications

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inherent in the model structure and mathematical descriptions of various processes could lead to the uncertainty of model results. In order to get more accurate, reliable model results, more spatially and temporally distributed data (land use data, precipitation and discharge) should be obtained by remote sensing or field investigation, and the hydrological physical processes (evapotranspiration, infiltration, runoff generation and runoff concentration) should be understood deeply, especially in the semi-arid area. The detailed uncertainty analysis of the model will be done in the future study.

Comment: Page 2437 (line 7): The authors introduce another uncertainty in their analysis, i.e climate change. How sure are the authors that climate change has no impact on the fluxes they are discussing in this paper? Can they quantify the impact of climate change in the fluxes they are discussing in this paper?

Answer: The objective of this study is quantifying the impact of land use and land cover change on the evapotranspiration (green) and runoff (blue water). The impact of climate change on hydrological processes was not studied in detail in this paper. We took the actual observed meteorological data as the model input. That's to say, the situation of climate change, if any, has been considered in this research. The climate change certainly has an impact on the hydrological processes, while the climate change was not drastic within the Laohahe Catchment. For example the annual precipitation series has no remarkable decreasing tendency. Thus we think the main reason for the decrease of streamflow is human activities, i.e. water use by increasing abstraction from river channels and groundwater aquifers.

Comment: It would be interesting to produce a cumulative runoff map over the study area for the years 1980, 1989, 1996 and 1999 and compare with the land uses indicated in Figure 3 and the ET maps in figure 7.

Answer: I am not sure whether the "cumulative runoff map" as mentioned in the comment is Figure 7. I am so sorry that the Figure 7 was not illustrated clearly, and brought you misunderstanding. The years of 1980,1989,1996,1999 in the Figure 7 show that the mean annual potential evapotranspiration in the period of 1980-1999 was calculated under that year of land cover scenario. There are 4 separate maps in the Figure7, and take the first map for example. It shows the spatial distribution of mean annual potential evapotranspiration in the period of 1980-1999 calculated under the 1980 land cover scenario. The Figure 7 was revised for clear illustration. Figure 7 shows that the spatial distribution of annual potential evapotranspiration was closely connected with the land use and land cover. Comparing Figure3 and Figure 7, one can draw the conclusion that the area with the forest land has a larger annual potential evapotranspiration, and the area with the grass land has a smaller one within the Laohahe Catcnment.

Comment: A good hydrological model should capture as much as possible the processes in a catchment in order to achieve a good simulation. From Figure 6, it is clear that the model used in this study could not capture the inherent dynamics of the catchment during the dry season. Then, what benefit can we get by using this model?

Answer: Thank you very much for giving us this useful comment. I agree that a good hydrological model should capture as much as possible the processes in a catchment in order to achieve a good simulation. As discussed in the paper, the effect of human activities is more drastic in the semi-arid area than that in the humid area besides less precipitation. Thus the hydrological process in arid area is always simulated worse than that in the humid area. There was no observed flood event corresponding to the precipitation after July in 2004 (Figure 6). That caused the poor simulated performance. It is obvious that human activities, i.e. reservoir storage, water abstraction out of river channel and groundwater aquifers resulted in streamflow decrease in 2004. If the data of reservoir storage and water abstraction from rivers and groundwater aquifers were obtained and returned to the streamflow, the simulated performance would be improved. Although poor performances exist in some years especially after 1990 due to human activities, the simulated performances before 1990 are acceptable. Thus this model can describe the relationship between the precipitation and runoff basically and

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could be used to explain how human activities have impacts on runoff quantitatively.

Comment: Page 2440: What is groundwater runoff?

Answer: Groundwater runoff is one kind of runoff, moving under land surface. Due to the difference of flow routing speed, runoff components are divided into surface runoff (moving quickly) and groundwater runoff (moving slowly) in this distributed hydrological model.

Comment: Page 2442 (Line9-19): What lessons can we learn from the approach applied in this paper? Can the authors advice other researchers in other parts of the globe to apply this model and or approach in quantifying the effects of land use change on green and blue water?

Answer: The text on page 2442, line9-19, gave some issues in this study that we have been aware of and presented some suggestions that we will do in the future. Although the distributed hydrological model used in this study is not ideal enough and need to be improved, it has capabilities to quantify the effects of land use change on green and blue waters. This study investigated the effect of land use and land cover changes on evapotranspiration and runoff. The conclusions form an important basis for the study of land use management, integrated water resources management, drought and so on.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 2425, 2008.