Hydrol. Earth Syst. Sci. Discuss., 5, S1559–S1564, 2008
www.hydrol-earth-syst-sci-discuss.net/5/S1559/2008/

Hydrology and Earth System Sciences Discussions

HESSD

5, S1559–S1564, 2008

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.

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Received and published: 22 October 2008

Reply to the referee comments hessd-5-S1413

Comment # 1) Table 1: The model was calibrated and validated for the 4 periods in corresponding to the land cover scenarios. The physical meanings of these parameters and the reason for their changes due to the different land cover should be explained in detail.

Answer # 1): Table 1 shows the 11 parameters in the conceptual hybrid runoff model. These parameters should be identified according to their physical meanings or observed in principle. However, those can not be achieved, because many variables have no observed values or observed values are not representative. In this study, the trial-error method was adopted for model calibration. Firstly the initial parameters were identified by empirical approach. Then the calculated runoff by the hydrological model was compared with the observed one. Thirdly the parameters were tuned to get the minimum error. Finally the rationality of the calibrated parameter values was checked according to their physical meanings. The physical meanings, constrainting factors, sensitivity of each parameter and the reason for their changes are explained in detail as follows: WUM, the tension water storage capacity of upper layer, is affected by the depth of the root zone, and the value of which is about 5 - 20 mm. WLM, the tension water storage capacity of lower layer, is affected by the soil structure and physical characteristics, and the value is about 60 - 90 mm. WM=WUM+WLM+WDM, which is the areal mean tension water storage capacity, affected by climate and depth of the soil. The value is physically equal to the difference between field capacity moisture and wilting point moisture content. The value of this parameter is about 100 - 150mm in humid area, and 200 - 300mm in arid area. The parameter WM is not sensitive to the simulated runoff, thus was kept invariable during the 4 periods. b, the exponential value of the tension water storage capacity curve, representing the heterogeneity of the spatial distribution of soil tension water storage capacity. The larger value of b means the more remarkable heterogeneity of the spatial distribution of soil tension water storage capacity. f0, fc and k are the parameters of Horton infiltration equation ft=fc+(f0-fc)exp(-kt). Where f0 is the maximum infiltration rate, fc is the static infiltration rate, and k is decay coefficient with time. f0 is affected by the soil texture and land cover, which is a sensitive parameter. The values of f0 did change less during the former two periods, but increased in the latter two periods, due to the effect of intensified human activities, e.g. cultivated land development for agricultural production, on runoff generation. The values of f0 during the latter periods were deviated from the real situation within the studied catchment and its physical concept to some extent. fc, insensitive parameter, was kept invariant during each period. k is affected by the soil texture. BX, the exponential of infiltration capacity curve, represents the heterogeneity of the spatial

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distribution of soil infiltration capacity. The larger BX means that the spatial distribution of soil infiltration capacity is much more heterogeneous. Kg is recession constant of groundwater storage, which is affected by geological condition. Ke and Xe are parameters of the Muskingum-Cunge method. Ke is the ratio of storage to discharge within the stream segment with the time of dimension, about 24 hour under the daily simulation. Xe is the proportional coefficient of discharge at upstream/downstream, about 0 - 0.5. Ke and Xe are affected by the slope of the stream channel.

Comment # 2) Table 4: This is the major results from hydrological simulation. The potential evaporation can be different due to the different definition; however the actual evaporation should have only one true value. How to validate the simulated actual evaporation? Can the actual evaporation be estimated directly by long-term water balance equation? If so, it is necessary to estimate the actual evaporation by water balance and compare with the model simulation.

Answer #2) : The actual evaporation in the Table 4 was calculated by the hydrological model on the basis of water balance equation. The actual evaporation can be simulated by long-term water balance equation on the assumption that the duration of 10 years meets the long-term condition. The table(http://boboyoung.512j.com/lxf/table1.jpg)gives the comparison between the actual evaporation directly from precipitation minus runoff and the evaporation by model simulation. It can be seen that there are no more differences between them.

Comment # 3) Figure 7: It is better to have the spatial distribution of actual evaporation too.

Answer #3) : Figure 7(b) and Figure 7(c) show the spatial distribution of mean annual actual evaporation and precipitation over the period of 1980-1999. It can be seen that the spatial distribution of mean annual actual evaporation was strongly controlled by the precipitation data, besides the potential evapotranspiration.

Comment # 4) Table 6: Changes in runoff ratio in the study catchment is significant-

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during 1964-2005. Discussion on the reason for this change is non-sufficient.

Answer #4) : Figure 8 shows that there is an obvious decreasing tendency in the observed annual runoff series, while there is no trend towards decrease in the series of annual precipitation in the catchment during the period of 1964-2005. These two phenomena resulted in the changes in runoff ratio in the studied area during 1964-2005. Based on the long-term water balance equation R=P-E, the increased evaporation is the direct cause of runoff decreasing. Water resources are mainly subjected to climatic circumstances and land surface characteristics. With the socioeconomic development, the amount of runoff is to some extent influenced by human activities, such as agricultural production, industrial development, and municipal construction, etc. Since the people's Republic of China was founded in 1949, the population, livestock, food production and GDP have increased tremendously in the Chifeng City which is the main city in the Laohahe Catchment (see Figure 9). The steep rise in food production and GDP occurred since 1978, because of the implementation of the policy of China's reform and opening to the world. All of these changes could cause the increase of surface water use and groundwater exploitation. Especially, water is drawn from river channel for cropland irrigation, industrial production and municipal utilization within or out of the studied catchment. Besides these, the land use and land cover changes could cause the change of the potential evpotranspiration in the basin, consequently affect the evaporation from the land surface to the atmosphere.

Comment # 5) Table 4: Based on the same climate data, the simulated actual evaporation (Ea) using different land cover scenario had little change. This means that the hydrological model was unable to simulate the land cover impact. How to explain the results using the same climate but different land cover in Table 4?

Answer #5) : The Laohahe Catchment is situated in the north part of China. Mean annual precipitation in the studied area was about 451 mm, and more than 90% of precipitation was consumed by evaporation. It is well known that the dominating factors of evaporation are potential evpotranspiration and available water (precipitation in a catch-

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ment). In the Laohahe Catchment the precipitation is much smaller than the potential evaporation. That is to say the actual evaporation is mainly limited by the precipitation. This was also illustrated by the figure 7(b) and 7(c). Figure 10 shows the change of simulated interception evaporation, soil evaporation and plant transpiration in each year of 1964-1979 under 1980 and 1996 land cover scenarios. As land cover changes from 1980 to 1996, as a result of the grass land changing into forest land and crop land in the catchment, the interception evaporation increased, while the soil evaporation and plant transpiration decreased. That also reduced the change of the simulated actual evaporation under different land cover scenarios, using the same climate data. In this study, an attempt was made on the impact of land-use and land-cover change on blue water (runoff) and green water (evaporation) by the hydrological model. As remarked above, evaporation occupies most component of precipitation in the catchment within the annual scale. Thus the impact of land-use and land-cover change on evaporation (green water) does occupy a little bit percentage of precipitation from the quantitative viewpoint. For instance, the slide (http://boboyoung.512j.com/lxf/slide.jpg) shows this evidence. Mean annual potential evapotranspiration for the period of 1964-1979 under the 1980 land cover scenario was 739.4 mm, and mean annual potential evapotranspiration for the period of 1990-1999 under the 1996 land cover scenario was 751.6 mm. The differences caused by climate change and land cover change were 0.9mm and 11.3mm, respectively. Thus, one can conclude that land cover change is the dominant factor of the potential evapotranspiration change between the periods of 1964-1979 and 1990-1999. While the change of mean annual potential evapotranspiration during the period of 1990-1999 caused by land cover change from 1980 to 1996 occupied a little bit percentage of mean annual potential evapotranspiration, about 2%. It is well known that the amount of actual evapotranspiration change under the same climate is smaller than that of potential evapotranspiration change. As a result, the actual evaporation (Ea) simulated by the hydrological model using different land cover scenario also had little change.

In addition, f0c, the parameter in the Table 1, should be changed into f0.

Figure legends and address links:

Figure 7(b). Spatial distribution of mean annual actual evaporation over the period of 1980-1999(http://boboyoung.512j.com/lxf/figure7b.jpg)

Figure 7(c). Spatial distribution of mean annual precipitation over the period of 1980-1999(http://boboyoung.512j.com/lxf/figure7c.jpg)

Figure 8. Precipitation, observed runoff and runoff ratio in the studied area during the period of 1964-2005 (http://boboyoung.512j.com/lxf/figure8.jpg)

Figure 9. The changes of population, livestock, food production and GDP in the Chifeng City during the period of 1949-2000 (http://boboyoung.512j.com/lxf/figure9.jpg)

Figure10. The changes of interception evaporation, soil evaporation and plant transpiration during the period of 1964-1979 under the 1980 and 1996 land cover scenarios (http://boboyoung.512j.com/lxf/figure10.jpg)

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