Dear Editor,

On behalf of my co-authors, we thank you very much for giving us the opportunity to revise the manuscript (Manuscript ID: **hess-2022-196**). We appreciate the comments on our manuscript entitled "*Attributing trend in naturalized streamflow to temporally explicit vegetation change and climate variation in the Yellow River Basin of China*" by Zhihui Wang, Qiuhong Tang, Daoxi Wang, Peiqing Xiao, Runliang Xia, Pengcheng Sun, Feng Feng.

Great thanks to the reviewers and editors, we have revised the manuscript carefully according to the comments. All the changes were high-lighted in the revised manuscript and the point-by-point response to the comments of the reviewers is also listed below. Please let me know if you require any additional information on our paper.

Looking forward to hearing from you soon.

Best regards,

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Response to Comments from Reviewer 1

General comments:

The manuscript assessed the effects from temporally explicit changes of climate variables and underlying surfaces on the streamflow trend using Variable Infiltration Capacity (VIC) model prescribed with continuously dynamic leaf area index (LAI) and land cover in Yellow River Basin. This study suggests that change in underlying surface has imposed a substantial trend on naturalized streamflow in Yellow River Basin. This topic is interesting and important for the water resources management in Yellow River Basin, especially for soil and water conservation measures and ecological restoration projects.

Response: Great thanks for your encouragement and recognition to our manuscript.

Specific comments:

Point 1: Line 156-159, the two-steps method was designed to consider time variant LAI in the VIC model simulation. Is it possible to use interannual change of LAI and land use in VIC model? In many hydrological models, the dynamical LAI and land use data are used. The version of the VIC model should be introduced.

Response: Great thanks for this comment. By default setting of VIC model, it only considers the climatology of vegetation (e.g., 12-month LAI), and the monthly LAI and land cover are stationary in different year during the simulation period, hence interannual change of LAI and land use cannot be considered in VIC model. The version of the VIC model used in this study is VIC 4.1.2.a. According to your comments, corresponding description has been revised, and the details are shown below.

By default setting of VIC model, it only considers the climatology of vegetation (e.g., 12-month LAI), and the monthly LAI and land cover are stationary in each year during the simulation period. Therefore, the impacts of continuous interannual change of LAI and land cover types on hydrological processes rarely be discussed in previous studies using VIC model (Xie et al., 2015; Yang et al., 2019; Zhai et al., 2021). In this study, the simulation scheme of VIC model (version 4.1.2.a) considering time-variant LAI was designed as the following two steps:

Point 2: Line 189, The monthly streamflow is evaluated by NSE, Bias and RMSE, which should be stated here, and calibration period and validation period, too.

Response: Great thanks for this comment. According to your suggestion, the NSE, Bias and RMSE have been stated, and calibration period and validation period are also been clarified. Corresponding description and equations have been added, and the details are shown below.

To find the optimal parameter set, an optimization algorithm of the multi-objective complex evolution of the University of Arizona (MOCOM-UA) from Yapo et al. (1998) was implemented, and Nash–Sutcliffe efficiency (NSE), relative bias (Bias) and root mean square error (RMSE) were used as the objective function to assess the model performance, as illustrated in Eq.(1)-Eq.(3). The automatic calibration was carried out by running the VIC model thousands of times during calibration period (1980-1993), of which the first two years (1980–1981) used for warm up, and the period of 1994-1999 is the validation period.

$$NSE = 1 - \frac{\sum_{i=1}^{N}(Q_{obs,i} - Q_{sim,i})^2}{\sum_{i=1}^{N}(Q_{obs,i} - \overline{Q_{obs}})} \quad (1)$$

$$Bias = \frac{\sum_{i=1}^{N} Q_{sim,i} - \sum_{i=1}^{N} Q_{obs,i}}{\sum_{i=1}^{N} Q_{obs,i}} \quad (2)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Q_{sim,i} - Q_{obs,i})^2} \quad (3)$$

where Q_{sim} and Q_{obs} are the simulated and observed monthly streamflow, respectively, $\overline{Q_{obs}}$ is the arithmetic mean of the observed monthly runoff, i is the ith month, and N is the total number of months in calibration period.

Point 3: Line 281, the vegetation degradation in the source region and urbanization in the middle reaches. It’s better to cite reference or data to support this attribution.

Response: Great thanks for this comment. Here is our mistake of the description. We just only want to descript the spatio-temporal change characteristics of interannual LAI during 1982-2018, without an aim to attribute the change trend of LAI. Decreasing LAI trend can be obviously seen in the source region in the Figure 4. Therefore, according to your great suggestion, corresponding description has been revised as below.

The downward LAI trend occurred in 15% of the basin which was mainly distributed in the source region.

Point 4: Line 315, the grey frames in Figure 7 are not necessary.

Response: Great thanks for this comment. It is better for displaying Figure 7 to remove the grey frames. According to your suggestion, corresponding figures have been revised, and the details are shown below.

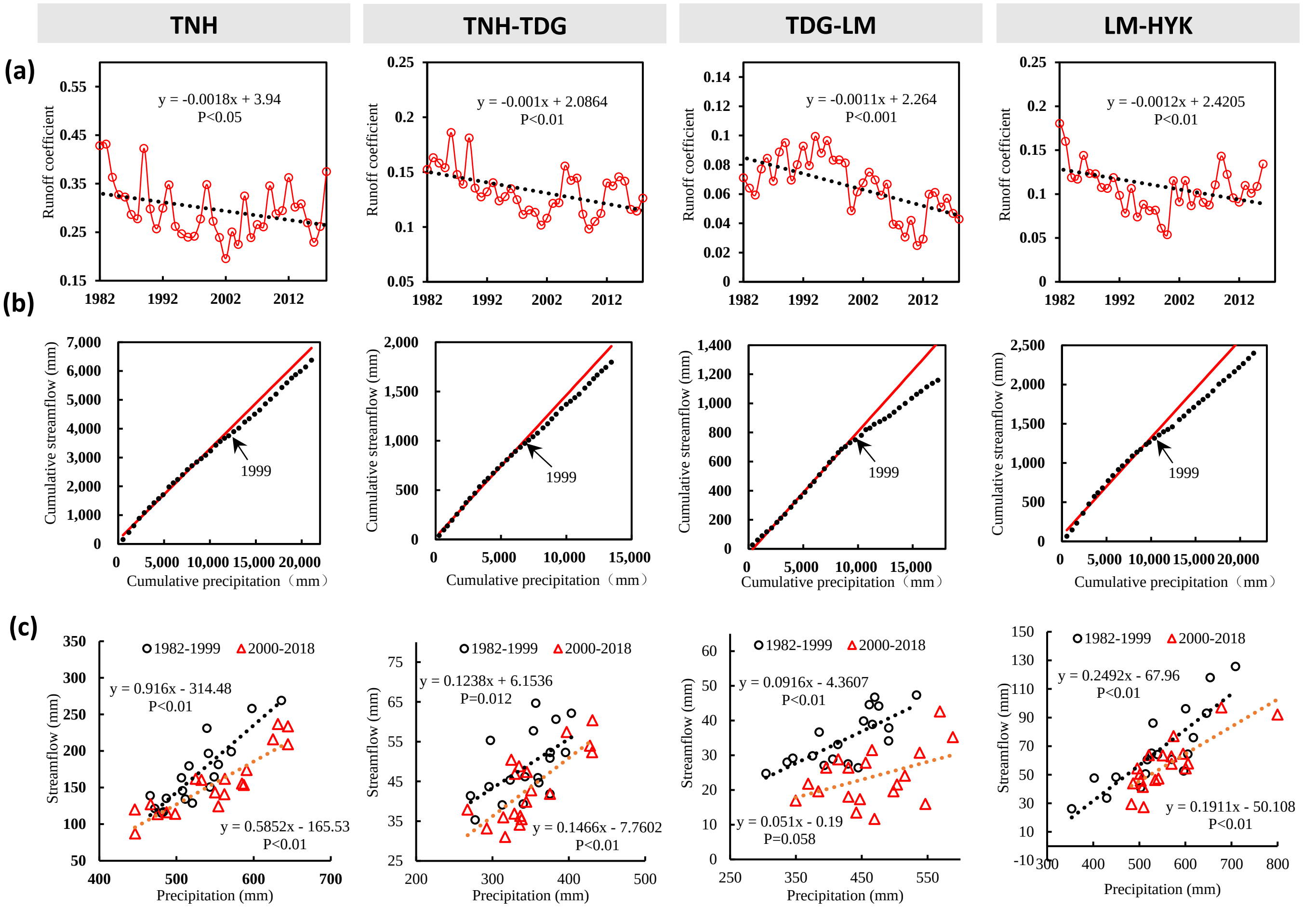

Figure 7. (a) The interannual change trend of annual runoff coefficiencts for 4 sub-regions, (b) precipitation-streamflow double mass curves for different sub-regions, and (c) precipitation-streamflow relationships in the two periods of 1982-1999 and 2000-2018 for 4 sub-regions.

Point 5: Line 342, add Table 3.

Response: Great thanks for this comment. Here is our mistake of the description. We have revised this mistake, and the details are shown below.

As per performance criteria given by Moriasi et al. (2007), simulation results indicate that the VIC model has a good performance in simulating hydrological processes in not only subbasins and sub-regions.

Point 6: Line 335-346, a table that summarizes the value of NSE, RMSE and Bias at different gauges in different period is helpful.

Response: Great thanks for this comment. A summary of the value of NSE, RMSE and Bias at different drainage areas in different periods is helpful for readers to understand the performance of VIC model simulation. According to your suggestion, except for adding the Table 4, corresponding figure 8 and description have also been revised. The details are shown below.

The monthly hydrographs and average seasonal cycles of the simulated and naturalized streamflows for different catchment regions are shown in the Figure 8, and the accuracy metrics of all simulations in the Figure 8 are summarized in the Table 4.

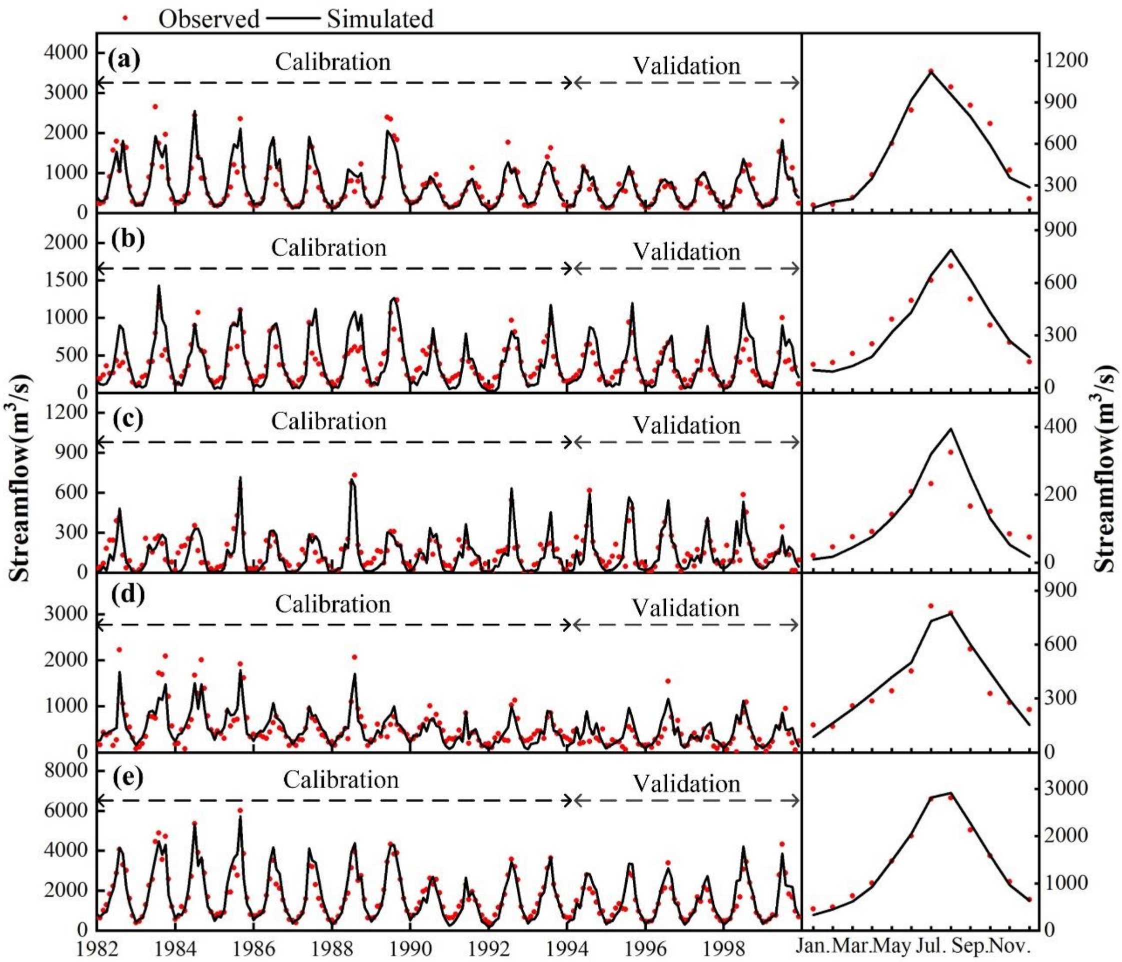

Figure 8. Comparisons of monthly streamflow and seasonal cycles of streamflow simulated by VIC and naturalized streamflow for different drainage areas during 1982-1999. (a) TNH, (b) TNH-TDG, (c) TDG-LM, (d) LM-HYK, (e) HYK

Table 4 Model performance metrics of monthly streamflows and seasonal cycles of streamflows in different drainage areas

Drainage areas	**Monthly streamflow (1982-1999)**						**Multi-year average of seasonal cycles of streamflow (1982-1999)**		
	Calibration period (1982-1993)			Validation period (1994-1999)					
	NSE	Bias	RMSE	NSE	Bias	RMSE	NSE	Bias	RMSE
TNH	0.86	0.1%	217.2	0.86	1.4%	149.7	0.96	-3.1%	64.6
TNH-TDG	0.5	3.3%	183.1	0.44	12.5%	169.5	0.87	-0.6%	66.2
TDG-LM	0.63	-11.7%	77.7	0.63	-7.0%	82.2	0.67	1.9%	48.5
LM-HYK	0.76	-4.7%	209.4	0.46	-10.3%	207.2	0.92	1.8%	60.0
HYK	0.89	-1.6%	387.4	0.8	6.9%	386.6	0.99	-0.7%	82.0

Point 7: Line 338, maybe the calibrated values of 6 soil parameters mentioned in Line 185 should be presented here.

Response: Great thanks for this comment. Here is a mistake of description in the number of calibrated soil parameters. We actually calibrated 7 parameters in the VIC model. These parameters have been added in the Table 3, and the details are shown below.

Table 3. Calibrated parameters of VIC model for different drainage areas over YRB

Drainage areas	b	D_s	D_{smax}	W_s	b_1	b_2	b_3
TNH	0.374	0.514	23.559	0.671	0.091	0.100	1.021
TNH-TDG	0.313	0.454	18.686	0.771	0.102	0.172	0.497
TDG-LM	0.135	0.056	7.427	0.354	0.264	0.824	1.107
LM-HYK	0.151	0.123	18.973	0.530	0.134	0.465	0.812

Point 8: Line 353, "For the HYK station, the contributions of all climate variables to the streamflow trend were positive excepting temperature, while larger negative effects from underlying surface change offset the slight positive effects of climate change on the streamflow trend (Figure 9).", it's better to move this sentence to Line 361 after the simulation result.

Response: Great thanks for this comment. According to your suggestion, this sentence has been move to the Line 361 after the simulation result, and the corresponding description has been revised as below.

From 1982 to 2018, the annual streamflow trend at HYK was -3.71×10^8 $m^3 \cdot yr^{-1}$, of which changes in interannual precipitation (P_inter), temperature (T_inter), wind speed (WS_inter), intra-annual temporal pattern of precipitation (P_intra), interannual LAI (LAI_inter), intra-annual temporal pattern of LAI (LAI_intra), interactive effects of climate variables and vegetation (Interactive), and residual underlying surface (Resi.) accounted for 15.1% (1.14×10^8 $m^3 \cdot yr^{-1}$), -23.5% (-1.77×10^8 $m^3 \cdot yr^{-1}$), 8.7% (0.66×10^8 $m^3 \cdot yr^{-1}$), 1.4% (0.1×10^8 $m^3 \cdot yr^{-1}$), -26.6% (-1.99×10^8 $m^3 \cdot yr^{-1}$) and -6% (-0.45×10^8 m^3·yr-1), -3.5% (-0.26×10^8 $m^3 \cdot yr^{-1}$), -15.2% (-1.14×10^8 $m^3 \cdot yr^{-1}$), respectively. For the HYK station, the contributions of all climate variables to the streamflow trend were positive excepting temperature, while larger negative effects from underlying surface change offset the slight positive effects of climate change on the streamflow trend (Figure 9).

Point 9: Line 352-380, a table is needed to summarize the value of impacts and relative impacts rates shown in Figure 9.

Response: Great thanks for this comment. A summary of the value of impacts and relative impacts is very helpful for readers to understand the Figure 9. Therefore, a new table 5 and corresponding description have been added, and the details are shown below.

The impacts and relative impact rates of eight influencing factors on the annual streamflow trends in different drainage areas were calculated using Eq.(6)-Eq.(14), as illustrated in the Figure 9 and Table 5.

Table 5. Summary of the values of impacts and relative impacts rates of all influencing factors shown in the Figure 9

	TNH		TNH-TDG		TDG-LM		LM-HYK		HYK	
Influencing Factors	Impact ($10^8 m^3 \cdot yr^{-1}$)	Rate (%)	Impact ($10^8 m^3 \cdot yr^{-1}$)	Rate (%)	Impact ($10^8 m^3 \cdot yr^{-1}$)	Rate (%)	Impact ($10^8 m^3 \cdot yr^{-1}$)	Rate (%)	Impact ($10^8 m^3 \cdot yr^{-1}$)	Rate (%)
P_inter	0.31	16.1%	0.15	10.5%	0.59	29.8%	0.09	3.5%	1.14	15.1%
T_inter	-0.72	-38.0%	-0.48	-33.2%	-0.24	-12.1%	-0.33	-12.3%	-1.77	-23.5%
WS_inter	0.22	11.5%	0.18	12.8%	0.13	6.5%	0.13	4.7%	0.66	8.7%
P_intra	0.04	2.1%	-0.04	-2.6%	-0.20	-9.9%	0.30	11.2%	0.10	1.4%
LAI_inter	-0.16	-8.3%	-0.23	-16.3%	-0.60	-30.5%	-1.00	-37.5%	-1.99	-26.6%
LAI_intra	-0.03	-1.7%	-0.05	-3.3%	-0.12	-6.1%	-0.25	-9.4%	-0.45	-6.0%
Interactive	-0.02	-0.8%	-0.02	-1.6%	-0.06	-3.1%	-0.16	-6.0%	-0.26	-3.5%
Resi.	-0.41	-21.4%	-0.28	-19.7%	-0.04	-2.1%	-0.41	-15.4%	-1.14	-15.2%

Point 10: Line 500, the slope land changes into the flat terraces could dramatically decrease the surface runoff generation and should not be ignored. It will also induce the change of intra-annual temporal pattern of LAI as shown in Figure 11(d).

Response: Great thanks for this comment. Yes, you are right. The slope land changes into the flat terraces could dramatically affect the vegetation growth by altering soil moisture, and thus interannual change and intra-annual temporal patten change of LAI could be induced by variations in micro-topography. According to your comment, this point has been added in the end of the Section 5.2, and details are shown below.

Due to phenology determines the start and end time of vegetation growth and is highly sensitive to climate change (Liang and Schwartz, 2009; Fu et al., 2019), climate warming has played an important role in advancing the spring phenology and delaying autumn phenology, and consequently extended the length of vegetation growing period across the globe (Piao et al., 2019; Menzel et al., 2020), especially for the semi-arid and semi-humid regions of China (Wu et al., 2015; Chen et al., 2022). In addition, the variations in micro-topography from slope land into flat terrace significantly increase soil moisture (Bai et al., 2019), which could also inevitably alter inter-annual change and intra-annual temporal pattern of LAI.

Point 11: Line 519, Was the degradation of permafrost simulated in VIC model in this study? How about the setting? Please explain it.

Response: Great thanks for this comment. We didn't simulate the degradation of permafrost in VIC simulation in this study. Here we just want to discuss the possible underlying surface changes causing streamflow reduction (the residual factors in the Figure 9) in the source region according to previous studies. Some researchers have found it is highly possible that permafrost degradation has played a role in diminishing river runoff. According to your comment, corresponding discussion has been added in the Section 5.5 Uncertainties, and the details are shown below.

Due to the lack of water consumption data of coal mining and the effects of glaciers melting and permafrost degradation on the runoff generation were not considered during VIC simulation in this study, the impacts from coal mining, glacier and permafrost in analysing the relationship between non-vegetation underlying surface change and river runoff were not further clarified.