Dear Editor,

Thank you for your letter and the reviewer comments concerning our manuscript entitled 'Remote Quantification of the Trophic Status of Chinese Lakes' (*hess-2022-91*).

We have studied comments carefully and have made correction which we hope meet with approval. Revised portion are marked in blue in the revised manuscript. The main corrections and the responses to the reviewer comments are described below.

Thanks again for your time and help.

Yours sincerely

Sijia Li and Zhidan Wen on behalf of the authors.

Responses to Anonymous Referee #2' Comments

Dear reviewer,

We would like to express our sincere appreciation for your careful reading and helpful comments. These comments are all valuable and helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and addressed the points noted below.

Revised portion are marked in blue in the paper. The main corrections in the paper and the responds to the reviewer's comments and remarks are as flowing.

"Dear Authors,

The paper presents a framework to quantify remotely trophic states in lakes. The study was conducted in China, but the developed approach can be applied in other parts of the world for water quality management. The study is interesting and shows novelty. I have only a few comments:

Major comments:

1. The results on the spatio-temporal patterns of ungauged lakes are roughly described (section 3.5), although it is the end goal of the presented remote quantification approach. Please, describe the spatio-temporal patterns of trophic states in detail. Additionally: How long is the input time series used for the XGBoost model? Are there any trends of eutrophication? Also, the Authors claimed that trophic states in lakes are related to lake basin characteristics, climate, and anthropogenic activities. However, the presented results are not enough to support this affirmation. Please, compare basin characteristics, climate and anthropogenic activities to the predicted TSI.

Response: Thanks for your patient review. We are sorry our unobvious description about small title '3.5 Spatio-temporal patterns of trophic states in a large-scale overview' for the patterns of trophic states. This is because the MSI sensor equipped in Sentinel-2 was launched since 2015, and there are no images in early period like Landsat series satellites (1975-present) to provide the interannual variation of trophic state. The MSI revisit time in many parts of the world is 2-3 days. For higher latitudes countries (Sweden, Finland and Estonia), the revisit time of MSI is almost every second day due to the overlapping orbits (Toming et al., 2016). In mid latitudes countries (Italy), there is also revisit time 2-3 days (Pereira-Sandoval et al., 2019). However, China stretches over 135°-73°E and 53°-3° N, by way of example in DaGuangBa (Table 1, 18°58'N,109°00'E), there are only 75 scenes level 1C products per year due to less orbits, in comparison to 175 scenes per year in Võrtsjärv (Estonia, 26°1'E, 58°15'N). One MSI has 10 days revisit time at the equator. There are two Sentinel-2's in space and the orbits overlap closer to the poles. Secondly, many lakes, like Nam Co in Tibet (>4000 m), are hard to reach and the Sentinel-2 overpasses there are not as frequent as in many other places. In addition, frequent cloud cover in some areas often prevents getting suitable images for several weeks in a row. Hence, we selected some representative lakes to qualify spatial trophic states with a total of 139 cloud-free images in spring (Apr. and May.), summer (Jul. and Aug.) and autumn (Sep. and Oct.) to analyze annual variations using our the XGBoost algorithm. According to your suggestion, we revised this title as '*3.5 **Spatial and Seasonal patterns of trophic states: Five lake limnetic regions***'.

According to your suggestion, we revised manuscriptas following '*Previous studies have demonstrated that some lakes disappeared or increased numbers recently according to statistics from Ma et al. (2011). Thus, we selected some representative and stable lakes (N=555) to qualify spatial trophic states using the XGBoost algorithm. The preprocessing of MSI data were referred to the Fig.2, and a total of 139 cloud-free images in spring (Apr. and May.), summer (Jul. and Aug.) and autumn (Sep. and Oct.) covered investigated lakes were acquired. According to the different geographic and limnological types in China, lakes were divided into five limnetic regions (Wang and Dou 1998, Early National Investigation): Eastern Plain Limnetic Region (EPLR, N=123), Northeast Plain Limnetic Region (NPLR, N=37), Inner Mongolia-Xinjiang Plateau Limnetic Region (IMXPLR, N=56), Yungui Plateau Limnetic Region (YGPLR, N=15), and Tibet-Qinghai Plateau Limnetic Region (TQPLR, N=324) (Fig. 1 and Supplementary data).*

In general, there were significant seasonal variations in eutrophic state for lakes from the EPLR ($F=39.56$, $p<0.001$) and TQPLR ($F=5.0$, $p<0.05$) (Fig. 7). The averaged TSI in EPLR were 56.37 (Spring), 57.73(summer) and 54.26 (autumn) indicating serious eutrophication of investigated lakes, consistent with the results from Li et al., (2022). Recognizing that over 94% of the Chinese population lives in eastern watersheds with great demands of water use, this may be due to different water qualities management in provincial scales. Likewise, we found there was spatial heterogeneity of TSI results in TQPLR and some of which were the widespread saline lakes in Qinghai-Tibet Plateau with high reflectance in satellite images. On the contrary, there were no seasonal differences of TSI for lakes from IMXPLR, NPLR and YPLR, respectively. The eutrophic lakes dominated the proportions of the investigated lakes in the EPLR (93.5 %), followed by the NPLR (89.2 %), YGPLR (86.7 %), IMXPLR (69.6%) and TQPLR (3.7%) (Fig.8). It can be also found that mesotrophic lakes were found in the decreased order of TQPLR (45.7 %), IMXPLR (30.4%), YGPLR (13.3 %), NPLR (10.8 %) and EPLR (6.5 %), respectively. In comparison, most oligotrophic lakes (50.6%) were distributed in the TQPLR. '

We agreed with your comment, and we are sorry for our careless descriptions about 'trophic states in lakes are related to lake basin characteristics, climate, and anthropogenic activities'. In future work, we plan to produce long time series and large-scale trophic state products and analyze the driving forces results of basin characteristics, climate and anthropogenic activities. Our presented results are not enough to support this affirmation, and this sentence was deleted in revised manuscript. We hope that these revisions and the improved text will be satisfactory.

2. What are the limitations and uncertainties of this study? The limitations and uncertainties should be presented as a section in Discussion.

Response: Thanks for your patient review. According to your suggestion, we add the limitations and uncertainties of this study as a section in Discussion in revised manuscript as following

‘***4.4 Limitations, uncertainties and future***
Toward the United Nation's Sustainable Development Goal (SDG) 6.3.2, satellite imagery and machine learning still provides great potential for evaluating water qualities state from global observations, particularly in developing countries. Machine learning algorithms could serve as good alternatives for empirical and semi-analytical algorithms to quantify on large-scale spatial applications, which could avoid or minimize the errors. Our results further demonstrated machine learning algorithms could improve the accuracy of water quality models (e.g., TSI) when the linear regression was used to find sensitive band combinations with red/red edge bands. Previous studies (Li et al., 2021, 2022) found red and red edge band could help us to quantify the spatial and temporal changes of Chl-a concentration or a synthetic parameter-such as TSI with high Chl-a weight ratio-from regional lakes. It is enable us to use sentinel-2 or similar sensors equipped with these bands to capture records of TSI dynamics.
As a medium-resolution (10~60 m) satellite, Sentinel-2 MSI offers the potential to monitor small-size lakes and produce reliable TSI estimates. However, there are significant obstacles in generating a Sentinel-2 (~10m) lake TSI distribution, including the acquisition of high quality atmospheric corrected Rrs(λ) and massive computational overhead by C2RCC processor (Li et al., 2023). C2RCC processor designed for waters based on neural networks is data-driven approach and uses huge datasets collected from in situ and simulation measurements. In situ reflectance measurements were not conducted in these investigated Chinese lakes when sampling. Our recently study reported that C2RCC (SNAP 8.0) and Polymer (v4.13) processors both performed best with in situ field radiometry in typical lakes across China (Li et al., 2023), but the latter could work better when all bands are pooled together in derived algorithms. Considering the growing requirements of TSI products, more in situ measurements would be required to be added the already-implemented processors in following work.
In addition, there is a need for a robust model developed from different locations and optical water types that accounts for the interplay of different water quality parameters. Machine learning TSI model required a highly calibrated dataset, including high nutrients (e.g., TP >2.50 mg L^{-1} in this study) and Chl-a concentrations (>100 μg L^{-1} in this study). Likewise, for our developed universal TSI model, the feasibility application performances were different considering lake classifications. Hence, the extensive field–lab materials with complex source variations would be required first and water optical typologies further is a good compromise to develop groups of optimized algorithms in future. Nevertheless, we aim to provide technical operation approach, which could prompt more analysis responding to warming climate and anthropogenic activities. The strong linkages between reflectance and several trophic state defining indexes further underscore the potential of remote sensing for resources-limited countries meet their SDG goals.’
We hope that these revisions and the improved text will be satisfactory.

Minor comment:
1. Lines 100-101: “there are 117 million of lakes on Earth (Verpoorter et al. 2014)” This information was already provided before.
Response: We are sorry for our careless mistakes. In revised manuscript, we corrected these as following ‘
Inland water TSI has been produced for large lakes using MODIS sensor (Wang et al 2018).

However, this study is for more than 2000 large lakes (due to the spatial resolution of the sensor).'.

We hope that these revisions and the improved text will be satisfactory.