Response to Reviewer #1

I have one more suggestion. The title of the paper s "Nonlinear hydro-climatic controls on---", so that the nonlinearity is the focus of the paper, The revised manuscript analyzed both the linear and nonlinear relationship, but the analysis on the nonlinearity s not enough. Therefore, please give more details about the XGBOST model, and further analyze and/or discuss the nonlinear hydro-climatic controls on the Bahannao Lake.

Response:

Thank you for this insightful comment. We agree that a clearer demonstration of nonlinear hydro-climatic controls is necessary given the focus of this study. In the revised manuscript, we have substantially strengthened the methodological description and the analysis of nonlinear relationships in several aspects.

To further investigate the nonlinear responses of lake area to climatic variables, we introduced partial dependence plots (PDPs) derived from the XGBoost model. The PDPs illustrate the marginal response of lake area to variations in key climatic variables, including relative humidity (RH), precipitation (P), temperature (T), and potential evapotranspiration (PET). This analysis allows us to visualize the nonlinear influence of each factor on lake dynamics.

The PDP analysis has been conducted for both seasonal models and three historical periods, enabling a more comprehensive interpretation of hydro-climatic controls. The results reveal pronounced seasonal nonlinear responses and clear stage-dependent evolution in lake dynamics. Specifically, atmospheric moisture conditions dominate lake variability in spring and winter, precipitation plays a stronger role in summer, while evaporative demand becomes increasingly important in recent decades under warming climatic conditions.

These additional analyses provide stronger evidence for the nonlinear hydro-climatic controls emphasized in the title and significantly improve the interpretability of the machine-learning results. The new analyses and discussions have been incorporated in Section 3.3.2 (Lines 969 – 1039), and the corresponding figures have been added to illustrate the nonlinear relationships.

Lines 969-1039:

To further investigate the nonlinear relationships between lake area and climatic factors, partial dependence plots (PDPs) were generated for each season and period. The seasonal partial dependence plots (Fig. 19(a – p)) reveal pronounced seasonal differences and nonlinear responses of lake area to hydro-climatic variables.

In spring, lake area exhibits a clear threshold response to relative humidity (RH). When RH remains below approximately 34 – 35%, the lake area shows only minor variation. However, when RH increases to around 38 – 40%, the lake area rises rapidly, indicating that enhanced atmospheric moisture conditions can significantly support lake water storage. In contrast, PET shows a weak negative influence on lake area, while temperature exhibits a marked decline in lake area when it approaches approximately 10–11 °C, suggesting that intensified evaporation may suppress lake expansion. Precipitation shows only a limited influence, implying that spring lake dynamics are primarily controlled by atmospheric moisture conditions and evaporative demand.

During summer, precipitation demonstrates a pronounced nonlinear positive effect on lake area. When precipitation increases to approximately 200 mm, lake area expands rapidly, indicating that rainfall represents a major water input supporting lake expansion in the warm season. Relative humidity also shows a generally positive relationship with lake area, whereas increasing temperature leads to a clear decline in lake area, reflecting the strong evaporative effects under *high-temperature conditions.*

In autumn, lake area responds strongly to variations in PET, displaying a distinct nonlinear pattern. When ET_0 *approaches approximately 300 mm, lake area decreases sharply, whereas at higher PET levels the lake area shows partial recovery, suggesting a complex regulatory role of evaporative demand on lake water balance. Meanwhile, increasing temperature generally leads to a decline in lake area, highlighting the importance of evaporation processes in controlling autumn lake dynamics.*

In winter, RH exhibits a strong positive effect on lake area. When RH increases from approximately 40% to 50%, lake area increases markedly, indicating that atmospheric moisture conditions play a key role in regulating winter lake variability. Precipitation exerts a relatively weak influence, while temperature variations mainly affect lake dynamics indirectly through their influence on evaporation processes.

Overall, these results demonstrate that the response of lake area to hydro-climatic variables is highly nonlinear and strongly season-dependent, with atmospheric moisture dominating in spring and winter, precipitation controlling summer expansion, and evaporative demand exerting a stronger influence during autumn.

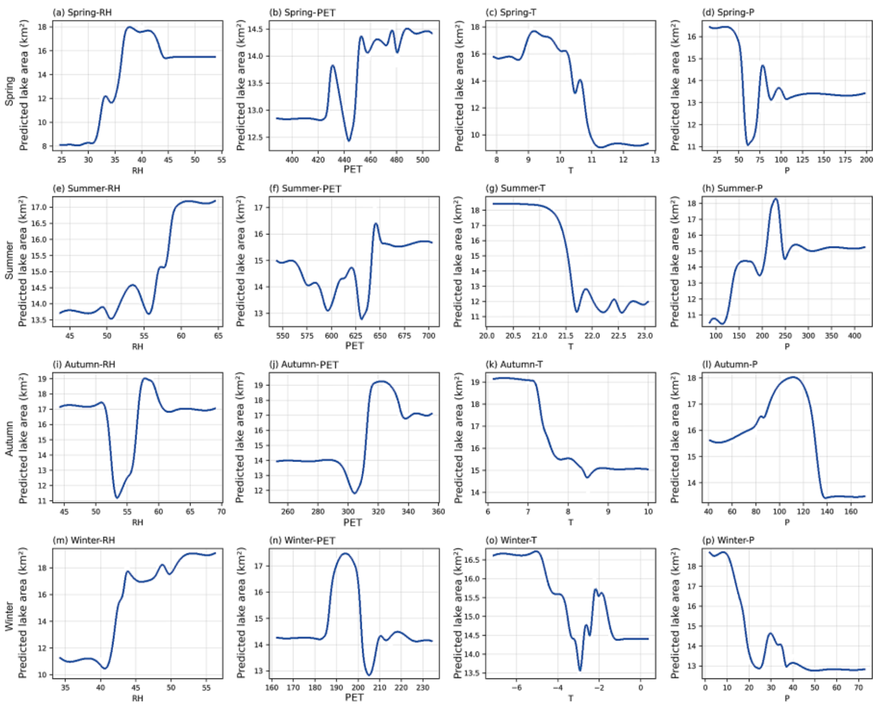

Figure 19. Seasonal partial dependence plots (PDPs) derived from the XGBoost model.

The partial dependence plots across the three periods (Fig. 20(a –l)) further reveal a clear temporal evolution in the hydro-climatic controls on lake area.During the first period, lake area shows a strong positive response to relative humidity (RH). When RH increases from approximately 30% to around 40%, lake area expands rapidly, indicating that atmospheric moisture conditions play a key role in sustaining lake water storage. Precipitation also exhibits a positive influence on lake area, particularly when precipitation exceeds approximately 80 –100 mm, suggesting that water supply conditions were an important driver of lake expansion during this stage. In contrast, PET and temperature show relatively weaker influences, indicating that evaporative demand played a less dominant role during the early period.

In the second period, the nonlinear responses of lake area become more complex. RH still exerts a noticeable influence on lake area, but the relationship becomes less monotonic compared with the earlier stage. Meanwhile, the influence of PET becomes more evident, suggesting that evaporative demand began to exert a stronger regulatory effect on lake dynamics. Precipitation continues to show a positive relationship with lake area, although the magnitude of the response is slightly reduced, indicating a gradual shift from water-supply dominance toward a combined influence of water supply and evaporation processes.

During the most recent period, the PDPs indicate that temperature and PET exert stronger impacts on lake area variability. Increasing temperature generally leads to a decline in lake area, reflecting enhanced evaporation under warming climatic conditions. Similarly, higher PET values correspond to reduced lake area, indicating that evaporative demand has become an increasingly important control on lake dynamics. In contrast, the influence of precipitation becomes relatively weaker compared with earlier periods, suggesting that the hydrological sensitivity of the lake has gradually shifted toward stronger evaporation-driven regulation.

Overall, the PDP analysis across the three periods suggests a gradual transition in the dominant hydro-climatic controls on Bahannao Lake, shifting from moisture-supply-dominated processes in the early period toward stronger regulation by evaporative demand under recent warming conditions.

These results highlight that lake dynamics in Bahannao Lake are governed by complex nonlinear hydro-climatic interactions, and that the dominant climatic controls have evolved over time.

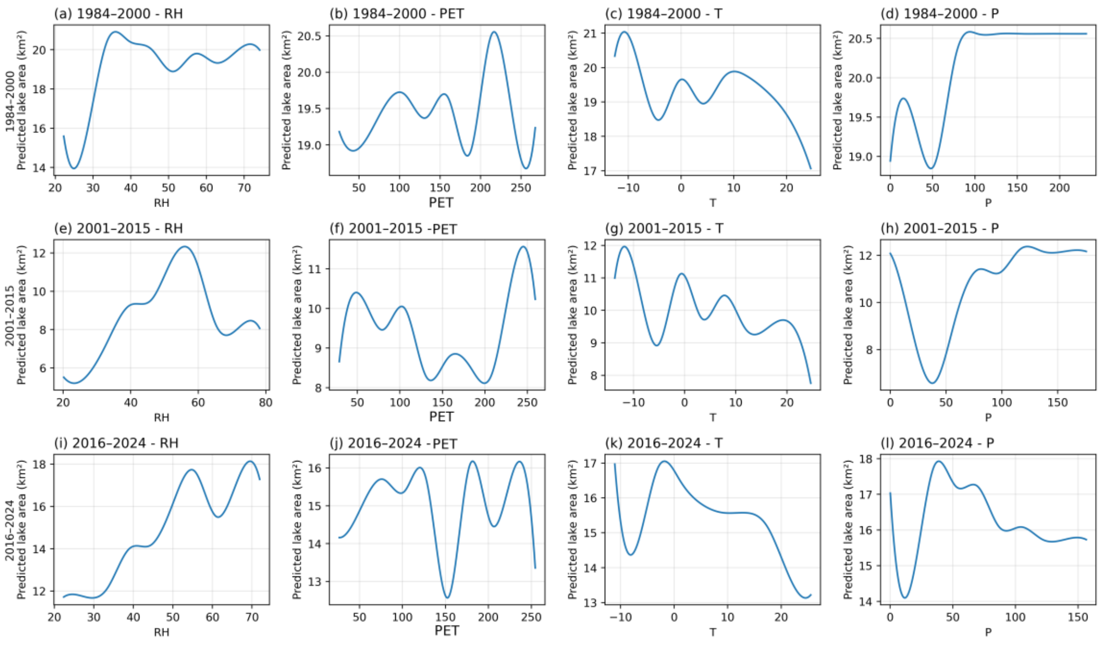

Figure 20. PDPs of hydro-climatic variables across three periods.

Response to Reviewer #2

1. Figure 1, the distribution of island in the South China Sea and the color annotations, it is necessary to check if they are appropriate. In Figure 1a, please verify if the name "Inner Mongolia" is appropriate.

Response:

Thank you for this helpful comment. We have carefully checked the map elements in Figure 1 and revised them accordingly to ensure cartographic accuracy and clarity. Specifically, the distribution of islands in the South China Sea and the corresponding color annotations have been re-examined and adjusted to follow standard geographic conventions. In addition, the label "Inner Mongolia" in Figure 1a has been verified and standardized as "Inner Mongolia Autonomous Region" to ensure consistency with the official administrative name. The revised figure has been updated in the manuscript.

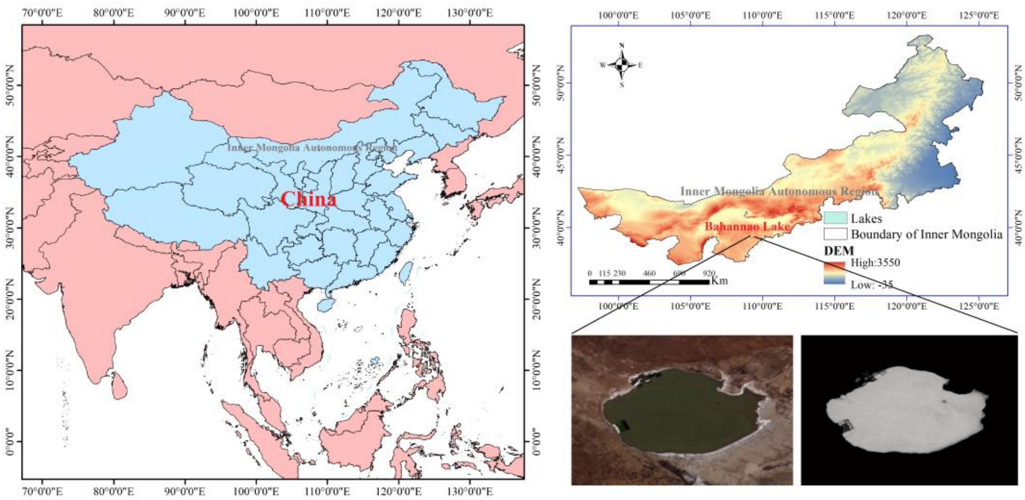

Figure 1 Overview map of the study area. Source: U.S. Geological Survey (USGS). Data are in the public domain.

2. In the spring of 2021, the area of the lakes increased rapidly and then decreased rapidly. What were the main reasons for this? Normally, the precipitation in this region during winter and spring is little.

Response:

Thank you for raising this important point. We carefully examined the hydro-climatic conditions during this period. The rapid expansion of the lake area observed in the spring of 2011 is likely related to short-term hydrological fluctuations caused by episodic precipitation events and temperature variations during the transitional season. Although precipitation in winter and early spring is generally limited in this region, occasional precipitation events combined with rising temperatures can accelerate snowmelt and temporarily increase surface runoff and inflow to the lake. However, due to the strong evaporative demand and limited water storage capacity typical of arid-region lakes, this short-term increase in lake area was quickly followed by a rapid decline.

To clarify this phenomenon, we have added additional explanations in the revised manuscript (Lines643 – 651) to discuss the potential influence of short-term climatic variability and hydrological responses during transitional seasons.

Lines643 – 651:

The rapid expansion of the lake area observed in the spring of 2021 may be related to short-term hydrological inputs. Although the precipitation in this region during winter and early spring is generally limited, occasional short-term precipitation events or snowmelt may temporarily increase surface runoff and inflow to the lake. In addition, as temperatures rise in late spring, enhanced evaporation and reduced inflow may lead to a rapid decrease in lake area. Therefore, the rapid increase and subsequent decrease in lake area in spring 2021 may reflect the combined effects of short-term hydrological inputs and seasonal evaporation processes.

3. In this article, regardless of interannual variations or seasonal variations, the correlation coefficient between the lake area and precipitation s very low, meaning that apart from precipitation, there should be important other water sources, Although this point was mentioned in the discussion section of the article, there is still a lack of convincing evidence, and more analysis in this regard is needed.

Response:

Thank you for this valuable comment. We agree that the relatively weak correlation between lake area and precipitation suggests that additional hydrological processes may influence lake dynamics. In the revised manuscript, we have expanded the discussion (Lines 1117 – 1125) to clarify that groundwater exchange and delayed hydrological responses may contribute to lake-area variability in this semi-arid environment. We also acknowledge that, due to the lack of long-term groundwater observations in the study area, these processes could not be explicitly quantified in the present study. In future research, we plan to integrate groundwater observations, hydrological modeling, and multi-source remote sensing data to further investigate groundwater – lake interactions and their influence on lake dynamics.

Lines1117 – 1125:

First, while remote sensing reliably captures surface-area dynamics, subsurface processes such as groundwater inflow and outflow were not explicitly quantified and may influence lake water balance. The relatively weak correlation between lake area and precipitation observed in this study further suggests that additional hydrological processes, such as groundwater exchange or delayed runoff responses, may contribute to lake-area variability in this semi-arid environment. However, due to the lack of long-term groundwater observations in the study area, these processes could not be directly evaluated in the present study.

Response to Editorial Comments

Comment:

Regarding figure 1: please add the statement "Source: U.S. Geological Survey (USGS). Data are in the public domain." into the caption with the next revision.

Response:

Thank you for the suggestion. The statement “Source: U.S. Geological Survey (USGS). Data are in the public domain.” has now been added to the caption of Figure 1 in the revised manuscript.

Lines 268 – 269:

Figure 1 Overview map of the study area. Source: U.S. Geological Survey (USGS). Data are in the public domain.