Dear Referee #1:

Thank you for your kind and encouraging comments on our study. Your comments and our responses to them are listed below.

- Powerful machine learning approaches were applied. What were the degrees of freedom of the machine learning approaches? What is the ratio of the degrees of freedom over the rather small number of 81 meteorological drought events?

RESPONSE: It seems these two problems were posed in order to investigate whether more degrees of freedom would cause the model to overfit the training data. In general, Regularization techniques and optimal model architectures are employed to ensure machine learning models are not overfitted and maintain low generalization errors. Therefore, degrees of freedom and model complexity always correspond very poorly (Janson et al., 2013), which is generally much less than the number of parameters in the model (Gao and Jojic, 2016). In this study, we used a Python package called PyCaret to construct these classifiers. L2 regularization method was selected in each model to avoid overfitting and maintain high calculation efficiency. The relevant description will be added to Section 2.4.3 in **Line 197-Line 204**.

MODIFICATION: In this study, each binary classifier was constructed using a Python package called PyCaret, which wraps several machine-learning libraries, including scikit-learn, XGBoost, LightGBM, CatBoost, spaCy, Optuna, and Hyperopt (Ali, 2020). The tune_model() function in the PyCaret package offers simple selection of optimal hyperparameters of each model. A 5-fold cross-validation was used to train and validate the classifiers in each model by setting "fold=5" in the create_model() function. In using the compare_models() function, the classifier with the highest summation of accuracy, precision, recall, F1 score, and Matthews correlation coefficient was selected as the optimal model. To avoid overfitting and maintain high calculation efficiency, the L2 regularization method was selected for each model by setting the parameter "penalty='l2'".

- According to Fig. 7 propagation probability is nearly exclusively determined by the

severity of the meteorological drought which would meet common expectations. In contrast, any effect of duration or area is hardly discernible. Please compare the performance of the machine learning approaches to that of a multivariate linear regression

RESPONSE: We agree and can see your point. In this study, machine learning models were used to determine whether a meteorological drought event has propagating potential. It is therefore a binary classification question. We have added Figure 9 and a description related to it in Section 3.4 in the revised version.

MODIFICATION:

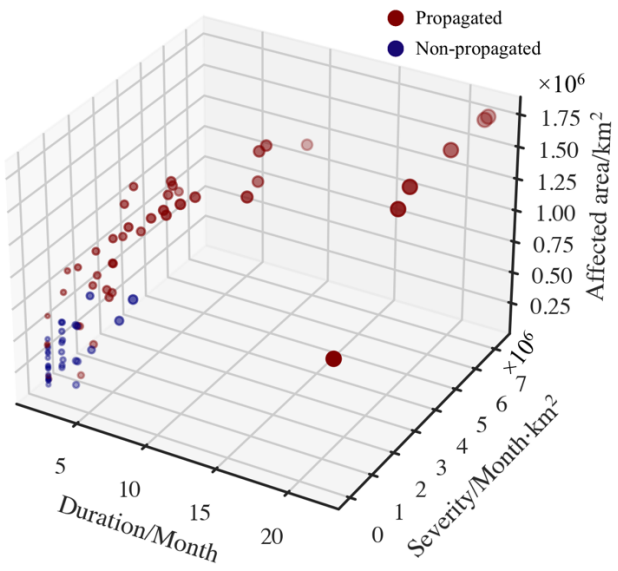

Figure 9 Three-dimensional diagram showing characteristics of meteorological drought events. Larger circles indicate greater severity.

As can be seen in Figure 9, propagated meteorological droughts have greater severity, larger affected area, and longer duration than non-propagated droughts.

RESPONSE: We agree that any effect of duration or area is hardly discernible. In this study, meteorological drought and ecological drought with genetic relationship were extracted on the basis of a certain spatio-temporal matching rule. Therefore, the model constructed in this study only includes meteorological drought and ecological drought events that have genetic relationships. As a result, only 103 out of 184 ecological drought events were

induced by 81 out of 108 meteorological drought events. The severity of ecological drought thus can be predicted based on the characteristics of meteorological drought. We have added the relevant description below in Section 4.1 in the revised version.

MODIFICATION: Using this method, two types of drought events without spatial connection would be excluded (only 103 out of 184 ecological drought events were induced by 81 out of 108 meteorological drought events), and more drought characteristics, such as affected area and migration path could be extracted. This addresses the limited applicability of the traditional method to regions with large spatial extent, and provides more reliable information for quantifying relationship between characteristics of meteorological drought and ecological drought.

RESPONSE: We have included your recommendation and added multivariable linear regression in **Line 317-Line 324** in the revised version.

MODIFICATION: For comparison, ternary linear and ternary quadratic models were constructed based on 46 pairs of meteorological-ecological drought events (Table 8). The comparisons were made in terms of three independent variables, M_DS, M_DD, and M_DA, and one dependent variable, E_DS. As shown in Table 8, the R^2 of the ternary quadratic model was evidently higher than that of the ternary linear model, whereas the RMSE, AIC, and BIC were lower. This illustrates that M_DS, M_DD, M_DA, and E_DS follow a nonlinear relationship, and that the ternary quadratic model is more suitable for simulating their relationship. According to the ternary quadratic model, E_DS equals 1.4×10^6 month·km^2 when M_DA > 17.6×10^5 km^2 ∩ M_DD > 11.8 month ∩ M_DS > 7.5×10^6 month·km^2. These values correspond to the thresholds of moderate (1.7×10^6 month·km^2), severe (2.4×10^6 month·km^2), and extreme (4.6×10^6 month·km^2) ecological drought.

Table 8 Modelling E_DS with polynomial functions based on meteorological drought characteristics

Model types	Expression	Assessment metrics			
		RMSE	AIC	BIC	R^2
Ternary linear model	$E\_DS=4.85\times10^5+0.15M\_DS+4099.35M\_DD-1.20M\_DA$	9.24×10^5	1350.67	1357.89	0.58
Ternary quadratic model	$E\_DS=1.54-0.05M\_DS-16.91M\_DD-0.08M\_DA-1319.23M\_DD^2+0.03M\_DD\times M\_DA$	7.29×10^5	1085.75	1100.20	0.85

- Please check the use of definite and indefinite articles and the use of plural “s”.

RESPONSE: Thanks for the hint. We have checked them carefully to avoid grammar errors in the revised version and marked them with red color.

Details:

- 53-55: Who is “they”?

RESPONSE: Thanks for the hint. The sentence "In other words, they considered temporal connection of two drought types and ignored their spatial overlap, which may result in the miscalculation of drought propagation in regions with large spatial extent." has been changed to " In other words, the traditional statistical methods only consider the temporal connection between two drought types and ignore their spatial overlap, which may result in the miscalculation of drought propagation in regions with large spatial extent." **in Line 52-Line 54.**

- 73-79: Section “2 Study area” comprises only 6 lines and should be merged with the subsequent section 3, or at least with section “3.1 Datasets”.

RESPONSE: We agree. Section 2 has been changed to Section 2.1 in the revised version.

- 82-85: Verb is missing.

RESPONSE: Thanks for the hint. The sentence " Monthly meteorological data, including surface reflectance, temperature, relative humidity, atmospheric pressure, downward shortwave radiation, wind speed, and longwave radiation, obtained from the ERA5-land reanalysis dataset (https://cds.climate.copernicus.eu) issued by European Centre for

Medium-Range Weather Forecasts (ECWMF), which has a spatial resolution of 0.1° × 0.1° and covers the period of 1981–2021" has been changed to " Monthly meteorological data, including surface reflectance, temperature, relative humidity, atmospheric pressure, downward shortwave radiation, wind speed, and longwave radiation, was obtained from the ERA5-land reanalysis dataset (https://cds.climate.copernicus.eu) issued by European Centre for Medium-Range Weather Forecasts (ECWMF), which has a spatial resolution of 0.1° × 0.1° and covers the period of 1981–2021." in **Line 86-Line 89.**

- 91: Use lowercase letter in “Root”.

RESPONSE: Thanks for the hint. We have corrected it to "root" in **Line 95**.

- 98: Replace “deep phreatic buried depth” by “great depth to groundwater”.

RESPONSE: Thanks for the hint. We have corrected it to " great depth to groundwater " in **Line 101.**

- 112: Both “SEWDI” and “SEBS” need to be explained in a concise way. Referring to the Jiang et al. (2021) paper does not suffice.

RESPONSE: We agree and can see your suggestion. We have explained it in **Line 114-Line 120** in the revised version.

MODIFICATION: SEWDI follows a similar procedure as SPI, which includes the calculation of ecological water deficit (EWD), the selection of an optimal distribution for fitting monthly EWD series, and the inverse normal transformation of the cumulative density distribution of EWD. EWD is the difference between ecological water requirement (EWR) and ecological water consumption (EWC) (Chi et al., 2018; Jiang et al., 2021). Among them, EWR was calculated using the single crop coefficient method recommended by the Food and Agriculture Organization (FAO). EWC equals the actual evapotranspiration, which is derived from latent heat fluxes calculated by the surface energy balance system (SEBS) algorithm.

- 124: Should be “three steps”, not “two steps”.

RESPONSE: Thanks for the hint. We have corrected it to " three steps " in **Line 132**.

- 147: Delete “to”.

RESPONSE: Thanks for the hint. We have deleted "to".

- 200: Do you mean “Johnson S_B distribution”?

RESPONSE: Thanks for the hint. We have corrected "johnsonsb" to "Johnson S_B" in the full text.

- 224: What does “DS” mean?

RESPONSE: DS represents drought severity. We have changed the name to its full form.

- 265: Please explain “itau method”.

RESPONSE: We have added " The Copula estimation can be eased by the itau method, which inverts Kendall's tau method (Demarta and McNeil, 2005)." in **Line 302-Line 303** for explaining "itau method".

- 280-297: Section 5.1 should be either part of the methods or of the results section.

RESPONSE: Thanks for your suggestion, we have moved Section 5.1 to the results section (Section 3.1) in the revised version.

- 349-352: Verb is missing.

RESPONSE: Thanks for the hint. The verb has been added to this sentence.

MODIFICATION: Monthly meteorological data, including surface reflectance, temperature, relative humidity, atmospheric pressure, downward shortwave radiation, wind speed, and longwave radiation, was obtained from the ERA5-land reanalysis dataset (https://cds.climate.copernicus.eu) issued by European Centre for Medium-Range Weather Forecasts (ECWMF), which has a spatial resolution of $0.1^{\circ} \times 0.1^{\circ}$ and covers the period of 1981–2021.

- Figure 3: I guess that the drought event numbers reflect chronological order, is that right? The colour scale indicates about the same meteorological-ecological drought event number for very different ecological and meteorological drought event numbers. E.g., green symbols show up for ecological drought event number 1-10, 30-50 and >150. How can that be? Is there something wrong with the colour coding of the symbols?

RESPONSE: You are right, we have corrected this mistake. Figure 3 has been replaced with the figure below in Figure 4 in the revised version.

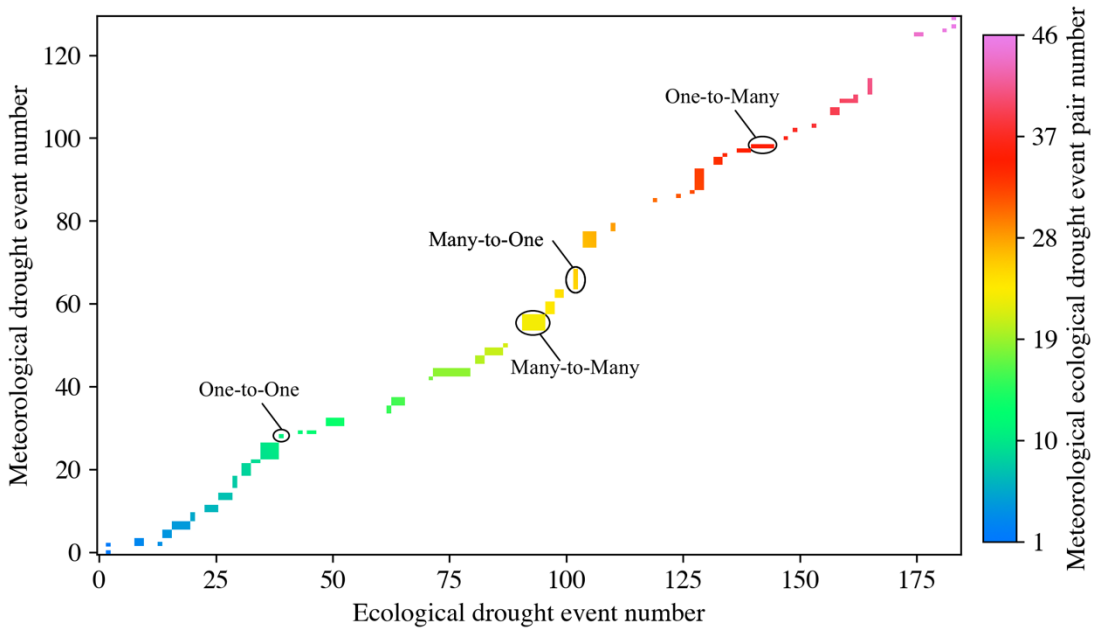

Figure 4: Identification results of paired meteorological and ecological drought events

- Figure 7: In the figure caption correct “exceeding” to “exceed”.

RESPONSE: Thanks for the hint. We have corrected “exceeding” to “exceed”.

References:

Ali, M.: PyCaret, PyCaret: An open source, low-code machine learning library in Python, 2020.

Demarta, S. and McNeil, A. J.: The t Copula and Related Copulas, International Statistical Review / Revue Internationale de Statistique, 73, 111–129, 2005.

Gao, T. and Jojic, V.: Degrees of Freedom in Deep Neural Networks, https://doi.org/10.48550/arXiv.1603.09260, 2016.

Janson, L., Fithian, W., and Hastie, T.: Effective Degrees of Freedom: A Flawed Metaphor, https://doi.org/10.1093/biomet/asv019, 2013.