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 the next version.

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). It is simple to select the optimal hyperparameters of each model using the tune_model() function in PyCaret package. A 5-fold cross-validation was used to train and validate the classifiers in each model by setting "fold=5" in create_model(). In using 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, L2 regularization method was selected in each model by setting 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 will add Figure 9 and a description related to it in Section 3.4 in the next version,.

MODIFICATION:

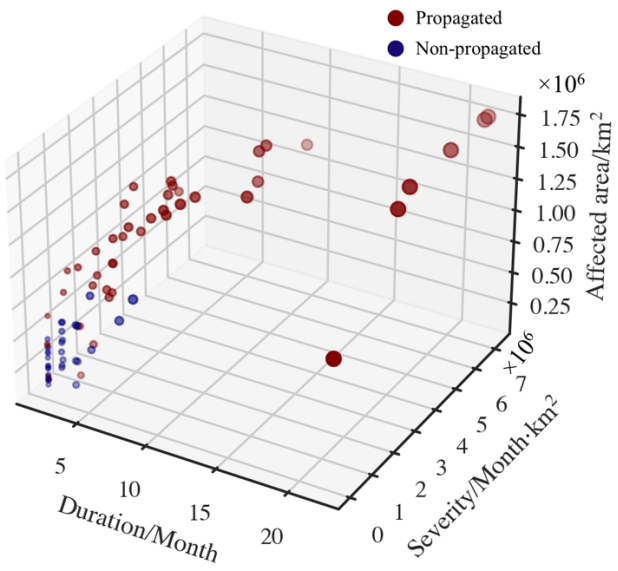

Figure 9 Three-dimensional diagram showing characteristics of meteorological drought events. Larger circles indicate greater severity.

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. Severity of ecological drought thus can be predicted based on the characteristics of meteorological drought. We will add relevant description below in Section 4.1 in the next 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 will include your recommendation and add multivariable linear regression in Section 3.4 in the next version.

MODIFICATION: As a comparison, ternary linear model and ternary quadratical model were constructed based on 46 pairs of meteorological-ecological droughts (Table 7). There three independent variables, M_DS, M_DD, and M_DA, and one dependent variable, E_DS. From Table 7, it is evident that the R^2 of ternary quadratic model is higher than ternary linear model, and RMSE, AIC, and BIC are lower. This illustrates that M_DS, M_DD, M_DA and E_DS follow a nonlinear relationship, and ternary quadratic model is more suitable for simulating their relationship. Using 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. It falls below 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 will check them carefully to avoid grammar errors in the next version.

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, traditional statistical method only 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."

- 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 will become Section 3.1 in Section 3 in next 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 $0.1^\circ \times 0.1^\circ$

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 $0.1^{\circ} \times 0.1^{\circ}$ and covers the period of 1981–2021."

- 91: Use lowercase letter in “Root”.

RESPONSE: Thanks for the hint. We have corrected it to "root".

- 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 ".

- 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 will explain it in next 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 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, the 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 ".

- 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 represent drought severity. We would change the name to its full form.

- 265: Please explain “itau method”.

RESPONSE: We have added "The itau method makes parameter estimation for Copula easier by inverting Kendall's tau method (Demarta and McNeil, 2005)." 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 will move Section 5.1 to the results section (Section 3.1) in next 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 will be replaced with the figure below in the next version.

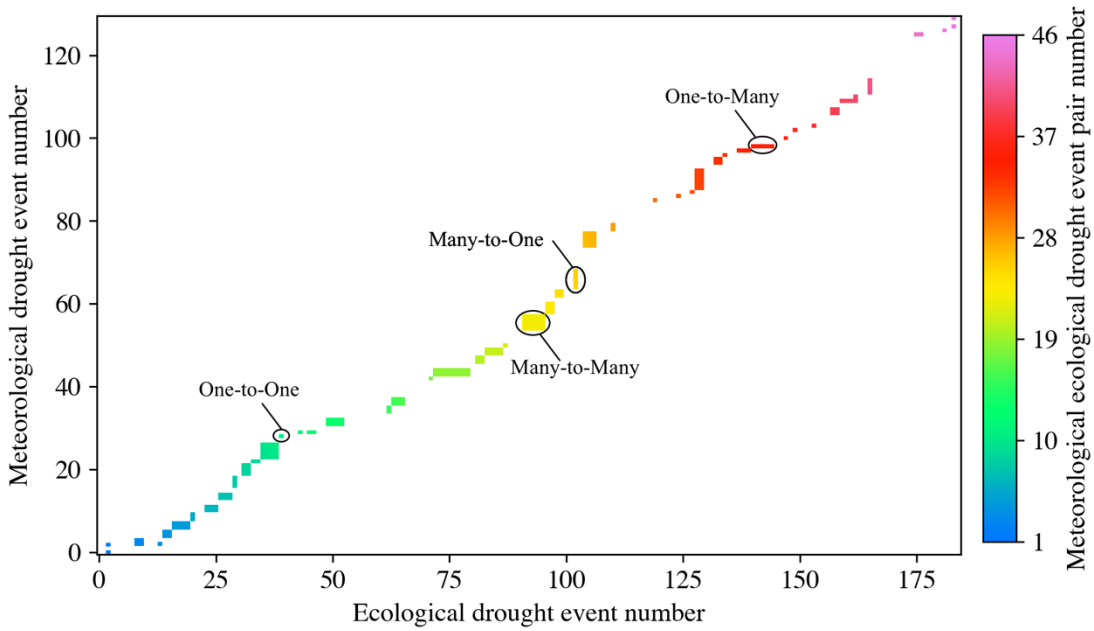

Figure 4: Identification results of paired meteorological and ecological drought events

- 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.