Manuscript Number: NHESS-2022-118

We sincerely thank the Reviewer 2 for the time in effort on reviewing our manuscript with many insightful comments. We believe that we have addressed each of the comments carefully and properly, while improving the quality of paper significantly. We hope that the changes listed below are acceptable for publication. In addition, we have made significant changes in all the relevant main text body, which could be aligned well with our responses to the comments in the revised manuscript. The changes made in the revised manuscript are highlighted in blue to facilitate their identification.

General Comment: This manuscript compared the skill of four machine learning algorithms, including multiple linear regression (MLR), support vector regression (SVR), random forest regressor (RFR), and eXtreme gradient boosting (XGB) for snowfall estimation in South Korea. Meteorological data (minimum temperature, maximum temperature, precipitation, and relative humidity) from 1991–2020 during the winter season (October to April) collected from the automated synoptic observing system, and geographic data (latitude, longitude, and altitude) were used as the input variables and the measured snow depth was used as the output variable for machine learning model training. The results indicate the RFR performs the best among the four machine learning algorithms with an R^2 of 0.64.

The work is interesting, however, the main drawback of this work is that it is too basic and simple. A great deal of similar works have been carried out in previous studies, and some of them have been summarized by the authors (Line 55-97). In the introduction, the authors only mentioned such previous works, but did not point out the problem which remains to be solved in the current work (i.e., the motivation of this study). In other words, if the paper is only a simple imitation of previous studies, it is not innovative.

Response: First, thank you for positively viewing our research ideas, with very insightful comments listed below. This study is a study to evaluate the applicability of various regression machine learning methods for predicting heavy snowfall in South Korea. Among the machine learning algorithms used in previous studies, models with good regression results were selected and applied to this study.

The snowfall prediction model of this study used four machine learning algorithms (MLR, SVM, RF, XGB) to learn the meteorological factors and geographic factors collected through the 102 ASOSs. This model will be used for GIS-based predicted snowfall distribution according to future RCP climate change scenarios. The four machine learning algorithms were selected as regression models for the purpose of prediction, not for identifying the cause of the heavy snowfall, and grid search and k-fold cross-validation techniques were used to improve learning performance. In addition, it is meaningful that geographic factors (latitude, longitude, altitude) as input data that were not considered in the study of snowfall prediction in Korea.

We have re-written the Chapter 1 to clearly present this research's superiority such as contributions and novelty, as follows:

Lines 95-110

Prediction of snowfall in previous studies is a non-linear process in which precipitation, temperature, relative humidity, and geographic variables are variously related. Various machine learning techniques that can take this non-linear process have shown good results in predicting the amount of snowfall. This is because nonlinear activation functions (Sigmoid and Tanh) are used in machine learning algorithms to explain the nonlinear relationship between input factors(Tabari et al., 2010). However, the prediction results may vary greatly depending on the regional research scope and the characteristics of the input variable data used for model development. In this study, South Korea as the study area, input variables not applied in existing domestic studies from previous studies were synthesized and heavy snowfall prediction was performed using an excellent machine learning algorithm. In addition, the predictive model derived through this study can be used for GIS-based predicted snowfall distribution according to future RCP climate change scenarios and heavy snowfall disaster management.

Comment 1

Line 41-45: add references.

Response: We added 4 more references of news article webpages for the heavy snowfall events.

1. Associated Press. (2018). *Waves of Winter Storms Kill at Least 16 in Europe*. The Weather Channel.
2. Deutsche Welle. (2020). *Japan: Heavy snowfall leaves thousands stranded*. Deutsche Welle.
3. France24. (2021). *Huge snowstorm blankets US East Coast, halting travel and vaccinations*.
4. United Press International. (2019). *Major winter storm kills 4 in Germany and Austria*. Gephardtdaily.

Line 36-42

In February 2021, shipments of COVID-19 vaccines to New York, USA, were suspended because of the heaviest snowfall in the past ten years(France24, 2021). In January 2019, a snowstorm in Austria killed 4 people and isolated 12,000 tourists(United Press International, 2019). In March 2018, heavy snowfall and cold waves in Europe killed 16 people and More than 350 flights were canceled(Associated

Press, 2018). In December 2020, Around 1,000 cars have been stranded and about 10,000 households cut off power in a snowstorm in Japan(Deutsche Welle, 2020).

Comment 2
Line 81: where is the reference of "Liang et al. (2015)"?

Response: We added the reference of "Liang et al. (2015)" in References, the last section of the manuscript.

Line 385-387

Liang, J., Liu, X., Huang, K., Li, X., Shi, X., Chen, Y., & Li, J. (2015). Improved snow depth retrieval by integrating microwave brightness temperature and visible/infrared reflectance. Remote Sensing of Environment, 156(February), 500–509. https://doi.org/10.1016/j.rse.2014.10.016

Comment 3
Section 2.1: only meteorological data were used in the study. Due to the limited spatial coverage of the stations, why the authors did not consider other large-scale data such as remote sensing data or model (reanalysis) based data?

Response: In this study, in addition to meteorological data, which is the actual observation data from the ASOSs, latitude, longitude, and altitude information, which are geographical data of the ASOSs, were used. To improve the prediction accuracy of the machine learning model, real meteorological data with high spatiotemporal resolution were used. The remote sensing data was not considered because of spatiotemporal resolution issues, the issue of paying money for data collection, and issues that could not be used in bad weather conditions.

We hope that this is acceptable and reasonable. Thank you.

Comment 4
Fig. 1: this figure lacks longitude and latitude information. Moreover, its quality can be improved, e.g., you can use the legend information to represent the stations but do not need to list all the station names.

Response: As requested, we have added longitude and latitude information at the border of figure. Also, we confirmed that the names of all the stations were unnecessary and removed them.

Line 128 (Figure 1.)

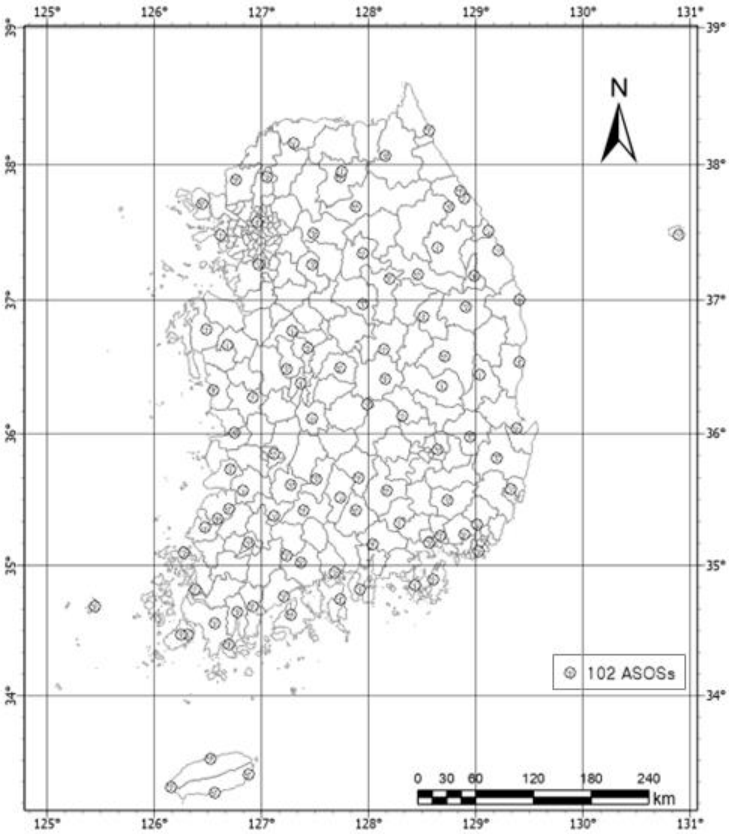

Figure 1. Study area – 102 ASOSs in South Korea

Comment 5 Line 129: where is the reference of "Ainiyah et al., 2016"?

Response: We added the reference of "Ainiyah et al. (2016)" in References, the last section of the manuscript.

Line 324-327

Ainiyah, N., Deliar, A., & Virtriana, R. (2016). The classical assumption test to driving factors of land cover change in the development region of northern part of west Java. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 41(July), 205–210. https://doi.org/10.5194/isprsarchives-XLI-B6-205-2016

Comment 6 Line 130: where is the reference of "Mallick et al., 2021"?

Response: We added the reference of "Mallick et al.(2021)" in References, the last section of the manuscript.

Line 395-398

Mallick, J., Alqadhi, S., Talukdar, S., Alsubih, M., Ahmed, M., Khan, R. A., Kahla, N. Ben, & Abutayeh, S. M. (2021). Risk assessment of resources exposed to rainfall induced landslide with the development of gis and rs based ensemble metaheuristic machine learning algorithms. Sustainability (Switzerland), 13(2), 1–30. https://doi.org/10.3390/su13020457

Comment 7

Line 140: should be seven inputs and one output?

Response: Yes, this should be "seven inputs and one output". We fixed in it in the revised manuscript.

Line 148-149

The pre-processed datasets consisted of the final seven inputs and one output variables, and four machine-learning algorithms (MLR, SVR, RFR, and XGB) were trained.

Comment 8

Fig. 2: isn't the average temperature excluded due to the high collinearity issue?

Response: Yes, average temperature was excluded because of high multicollinearity. However, the average temperature in the box of 'climate variables' was maintained because it was before the data preprocessing process. To avoid confusion for the readers, 7 inputs are displayed in the box of 'Input variables' and the Figure2 has been modified.

Line 158 (Figure 2.)

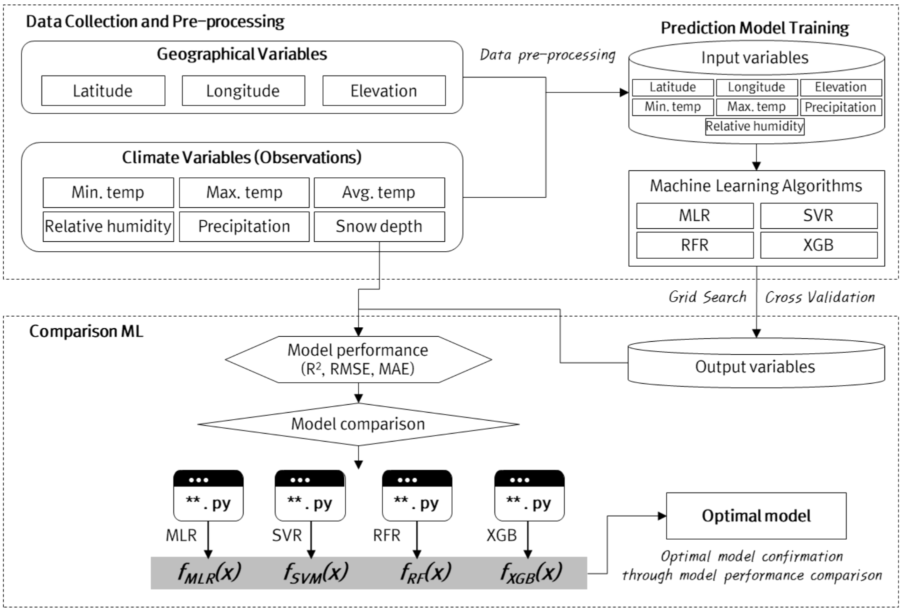

Figure 1. Research workflow

Comment 9
Line 153: it is better to add a section entitled "2.2 Machine Learning Methods" before "2.2 MLR". Moreover, there are numerous machine learning methods, why did you select the four methods?

Response: According to your kind review, the structure of chapter 2 has been revised and reflected in the revised version(2.2 Machin learning methods/2.2.1 MLR, 2.2.2 SVR, 2.2.3 RFR, 2.24 XGB). In the selection process of the machine learning methods, first, the regression model was suitable for predicting snowfall through the analysis of previous studies. Among the machine learning algorithms that support the regression, the algorithms with good results was selected in the preceding study like SVR, RFR and XGB. In the case of MLR, as mentioned in the manuscript, it was selected for comparison with the other three regression models.

Comment 10
Line 198: delete "Tianqi".

Response: Yes, this should be "(Chen & Guestrin, 2016)". We fixed in it in the revised manuscript.

Line 208

XGB (Chen & Guestrin, 2016) is known for its powerful performance, as demonstrated by recent studies.

Comment 11

Line 215: MSE and RMSE play the same role in the evaluation. You can only preserve RMSE.

Response: Yes, we fixed in it in the revised manuscript by deleting MSE and keeping only RMSE.

Line 224-225

The accuracy of the model was compared and verified using the MAE, RMSE, and R2 values(Guo et al., 2021)

Comment 12

Line 255-256: add unit for MAE, MSE, and RMSE.

Response: We added “cm" unit for MAE and RMSE.

Line 263-264

The RFR model exhibited MAE, RMSE, and R2 values of 1.65cm, 3.35cm, and 0.64, respectively, using performance evaluation criteria.

Comment 13

Table 4: add unit for MAE, MSE, and RMSE.

Response: We added “cm" unit for MAE and RMSE.

Line 271 (Table 4.)

Table 1. Comparative statistics of prediction models

Criteria / Models	MAE(cm)	RMSE(cm)	R^2
MLR	2.32	4.22	0.45
SVR	1.73	3.91	0.53
RFR	1.65	3.35	0.64
XGBoost	1.64	3.44	0.62

Comment 14

Fig. 5: add unit for snowfall.

Response: We added “cm" unit for snowfall.

Line 286(Figure 5.)

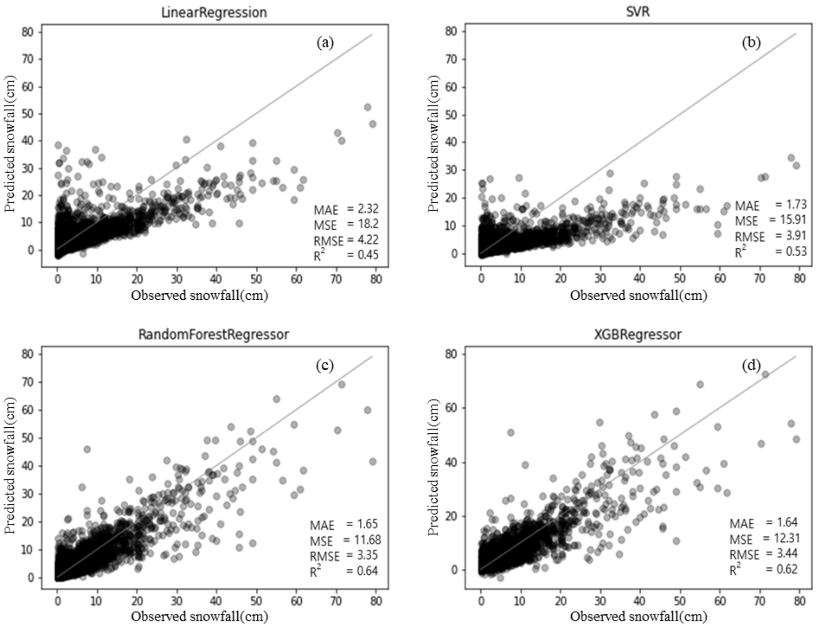

Figure 2. Correlation of observed and predicted snowfall results from (a) MLR, (b) SVR, (c) RFR, and (d) XGB