# Planning harvesting operations in forest environment using machine learning

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**Abstract**. This work use machine learning (ML) to identify the most suitable areas for two different forestry harvesting strategies, simulating the choices done during the planning phase in forestry operations. Features extracted from a high-resolution digital terrain model (DTM) are used for training several predictors over areas pre-classified manually by experts. When applied on the validation set, results show a Kappa index value of almost 0.92 for the random forest (RF) algorithm and 0.87 for the k-nearest neighbour (KNN). The sensibility of each feature is assessed, showing that both distance and height difference from the nearest road-side are more significant than overall DTM height values.

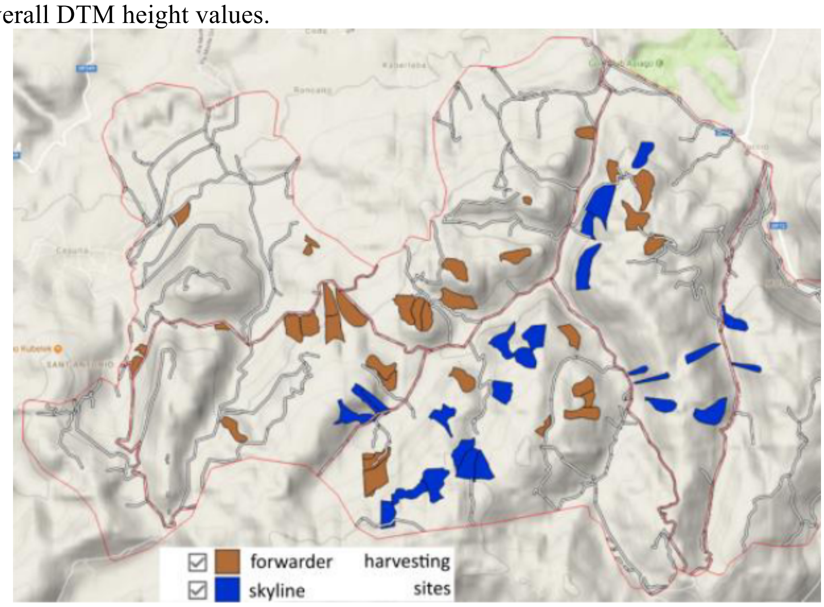


**Fig. 1.** Training and validation areas of the two forest harvesting strategies.

In the last decades, there has been a growing interest in using high-resolution remote sensing data and advanced spatial analysis techniques for forest planning [1]. Wood harvesting and wood transportation can take advantage of spatial analysis at the planning and operational level [2] especially in a complex situation such as roughness of terrain, steep terrain and low density of forest road network [4]. Forestry machines such as forwarded and skyline operates in a defined range of technical specifications and parameters. However, the decision-maker is inside the harvesting site and defining for each cell the best choice for harvest type.

The Pre-Alps area is largely covered by forests, which are an important economical asset of the region. The study area of 34.32 $km^2$ is located in the southern part of the Altopiano dei Sette Comuni in the Veneto region in Northern Italy. The digital terrain model (DTM) derived from an aerial laser scanning mission, has 1 m x 1 m resolution, which covered the area with more than 2 million cells. We assume a scenario where a decision-maker is in the harvesting site, and it is more natural to focus the attention on the accessibility of the area rather than to estimate the morphological aspect, such as roughness. Training and validation use a random stratified sample of 10% of the dataset. The dataset is composed of DTM, the CHM, the slope, the roughness, the distance from between the roads, and the elevation difference between each cell and the nearest cell of the road. The accuracy metric reported, applying 10 k-fold cross-validation, is the kappa index (K). A sensitivity analysis (SA) allows a better comprehension and interpretation of a black-box model, which ML method is.

Results show the RF is the slower algorithm, but it has a high Kappa index score of 0.92. KNN has K of 87.07. In contrast to the training set result, the KNN is slower than the Ctree. The Ctree is the fastest algorithm with a Kappa index of 0.78. SA measures the relative importance of inputs, where the elevation difference between the DTM and the roads are followed by the DTM values and the distance between road and cell. In contrast, the CHM, the slope and the roughness have less importance.

In this work we applied ML using morphological information for classifying a suitability map for two means of forest harvesting: forwarder and skyline. The results show the RF has the best performance in terms of Kappa index, but it is the slower in comparison to the KNN and the Ctree. However, the KNN accuracy is quite high, and the processing is very fast. The SA evidences that accessibility features have higher relative importance rather than the morphological features. The forestry machinery have some operational limitations, specified in terms of maximum slope or roughness of the harvesting site. However, the choice of the route based on the accessibility of the area is a human decision.

## References

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