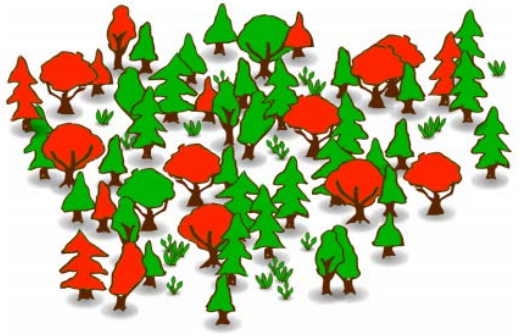
DECISION TREE

DEFINITION

- A schematic, tree-shaped diagram used to determine a course of action or show a statistical probability.
- **Each branch** of the decision tree represents a possible decision, occurrence or reaction.
- The tree is structured to show how and why one choice may lead to the next, with the use of the branches indicating each option is mutually exclusive.

DECISION TREE VS RANDOM FOREST



- "**Random forests** are a **combination of tree predictors** such that each tree depends on the values of a random vector sampled independently and with the same distribution for all trees in the forest."

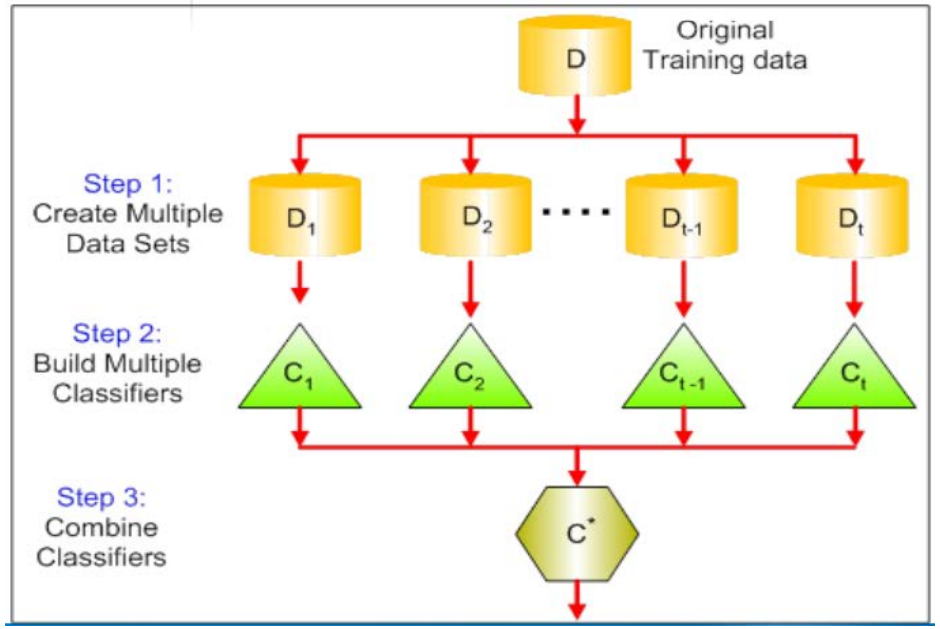


TABLE OF DATA SET

See first five observations

```
proc print data=sampsio.LAQ(obs=5);
 var LobaOreg MinMinTemp Aconif PrecipAve Elevation ReserveStatus; run;
```

Output 15.1.1: Partial Listing of LAQ

Obs	LobaOreg	MinMinTemp	Aconif	PrecipAve	Elevation	ReserveStatus
1	0	-5.970	44.897	89.623	1567	Matrix
2	0	-6.430	81.585	91.231	1673	Reserve
3	1	-0.893	229.330	154.610	685	Reserve
4	0	-7.476	45.875	110.330	1971	Reserve
5	0	-5.992	81.679	98.739	1597	Reserve

The LAQ data set consists of 30 measurements of environmental conditions, such as **temperature**, **elevation**, and **moisture**, at 840 sites.

These variables are treated as **predictors** for the response variable LobaOreg (our main object), which is coded as 1 if the lichen species Lobaria oregana was present at the site and 0 otherwise.

RE TO EE FOR LOBAOREG

GROW statement specifies the entropy **criterion for splitting the observations** during the process of recursive partitioning that results in a large initial tree

PRUNE statement requests **cost-complexity pruning** to select a smaller subtree that **avoids overfitting the data**.

```
ods graphics on;
proc hpsplit data=sampsio.LAQ;
  class LobaOreg ReserveStatus;
  model LobaOreg (event='1') =
    Aconif DegreeDays TransAspect Slope Elevatio
    PctConifCov PctVegCov TreeBiomass EvapoTra
    MoistIndexAve MoistIndexDiff PrecipAve Preci
    RelHumidDiff PotGlobRadAve PotGlobRadDiff A
    DayTempAve DayTempDiff MinMinTemp MaxM
    AmbVapPressDiff SatVapPressAve SatVapPressDif ReserveStatus;
  grow entropy;
  partition fraction(VALIDATE = 0.3, SEED =123)
  prune costcomplexity;
  output out = scored;
run;
```

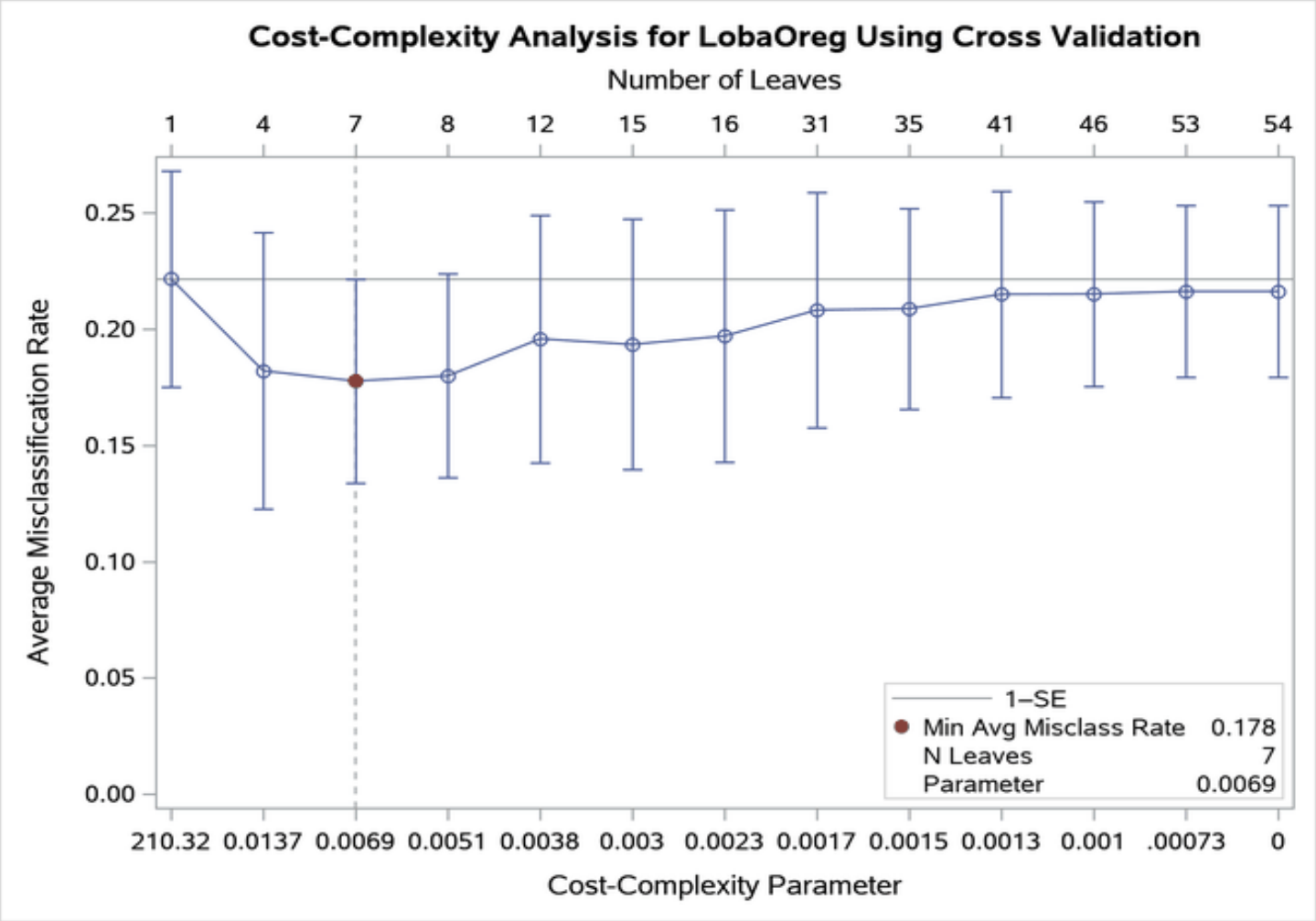
Partition fraction statement decided to divide data into trainset and test set. 'VALIDATE =0.3' means that train set is 70% and test set is 30%

Seed is a parameter for random selection.

In the case of **binary outcomes**, the **EVENT= option** is used to explicitly control the level of the response variable that represents the **event of interest** for computing the area under the curve (**AUC**), **sensitivity**, **specificity**, and values of the receiver operating characteristic (**ROC**) curves.

Note: These fit statistics do not apply to **categorical response** variables that have more than two levels, so the EVENT= option does not apply in that situation. Likewise, this option does not apply to **continuous response** variables.

MISCLASSIFICATION RATE (ERROR RATE) AS A FUNCTION OF COST-COMPLEXITY PARAMETER



Definition

- 전체 값에서 오차의 값이 발생한 비율
- 모형이 제대로 예측하지 못한 관측치를 평가하는 지표
- **Misclassification rate**는 전체 관측치 중 실제 값과 예측 치가 다른 정도를 나타내며 **1-accuracy** 또는 다음과 같은 식으로 나타낸다.

$$\text{error rate} = \frac{FP + FN}{TP + TN + FP + FN} = \frac{FP + FN}{P + N} = 1 - accuracy$$

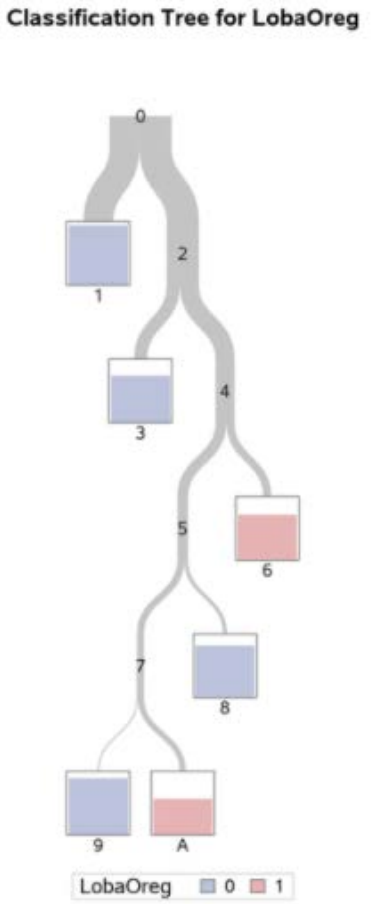
- **Selects the smallest subtree for which the misclassification rate is less than the minimum rate plus one standard error. >> Minimum error rate is at 7 leaves, so select subtree with six leaves.**

OVERVIEW OF FITTED TREE

- The **color** of the bar in each leaf node indicates the most frequent level of LobaOreg and represents the **classification level** assigned to all observations in that node.

- The **height** of the bar indicates the **proportion** of observations (sites) in the node that have the most frequent level.

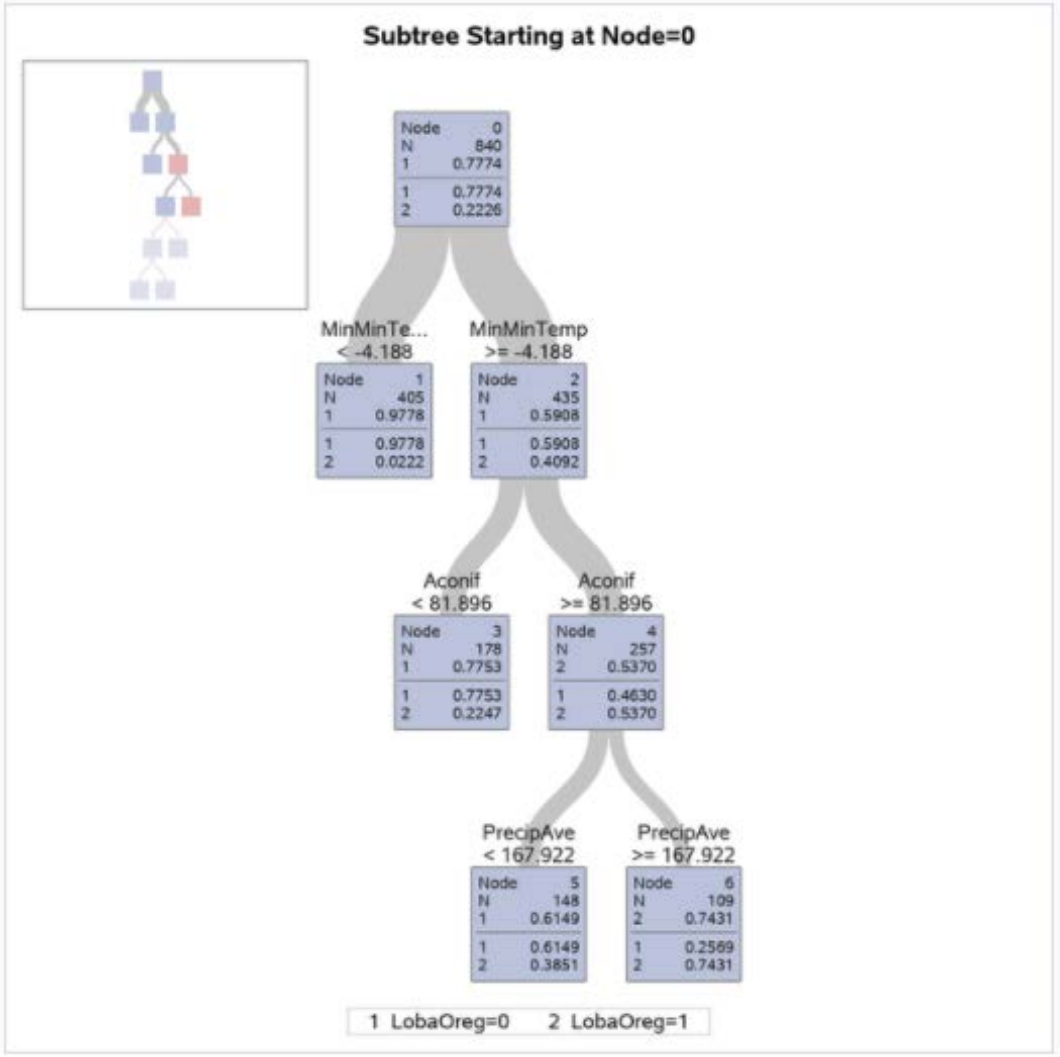
- Note: there is impurity in each leaf node. In other words, there can be LobaOreg observation values 1 and 0 in each node.



FIRST FOUR LEVELS OF FITTED TREE

- The diagram provides more detail about the nodes and splits in the first four levels of the tree. It reveals a model that is highly interpretable.

- The 435 sites for which **MinMinTemp** – 4.188 (node 2) are further subdivided based on the variable **Aconif**, which is the average age of the dominant conifer at the site. Lobaria oregana is present at **53.7%** of the 257 sites for which MinMinTemp – 4.188 and Aconif 81.896 years.

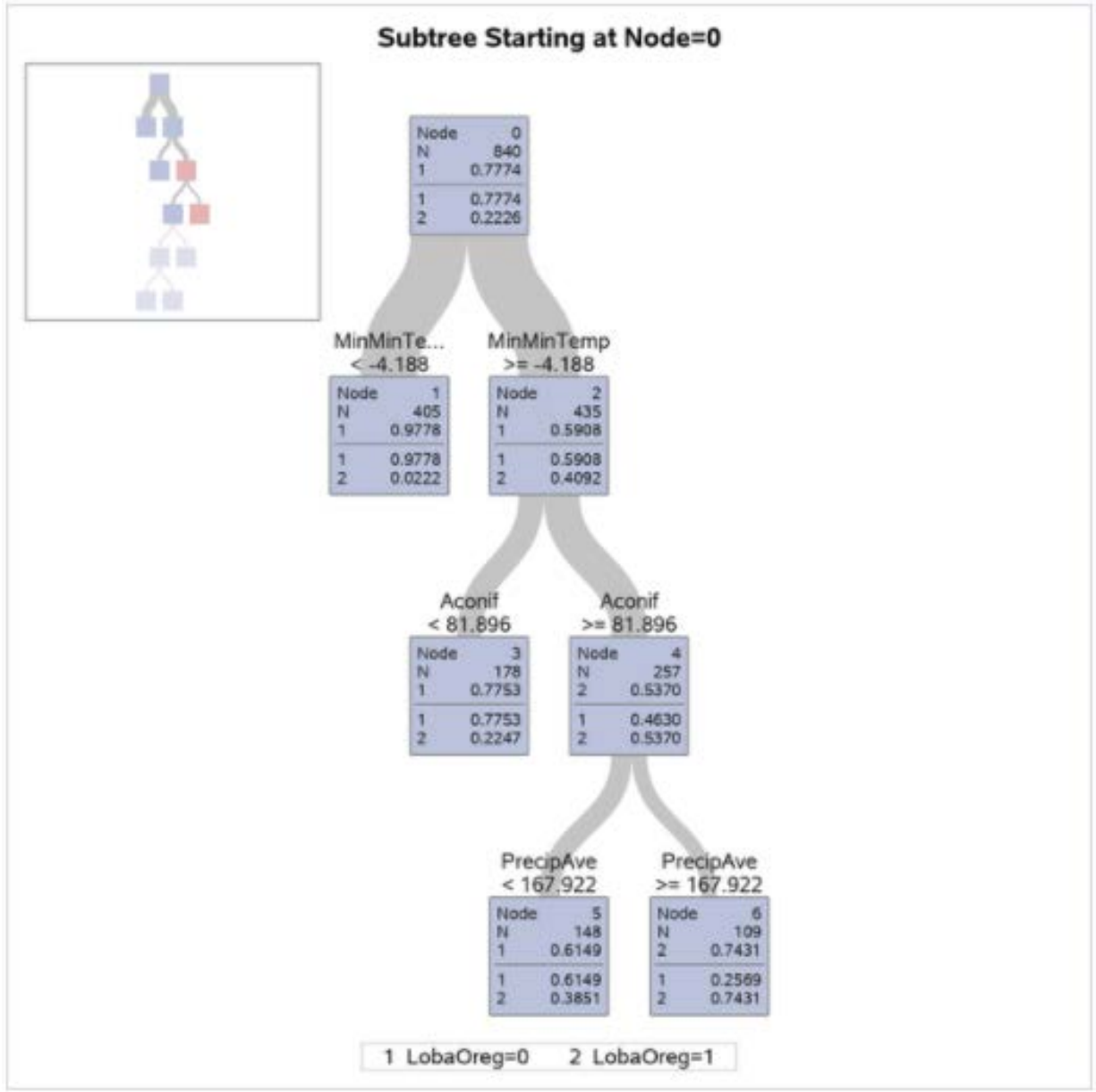


- The 257 sites for which Aconif 81.896 are further subdivided on the basis of **PrecipAve** (average monthly precipitation) with a cutoff value 167.922 mm.

- Lobaria oregana was present at **74.31%** of the 109 sites for which MinMinTemp –4.188, Aconif 81.896 years, and PrecipAve 167.922 mm.

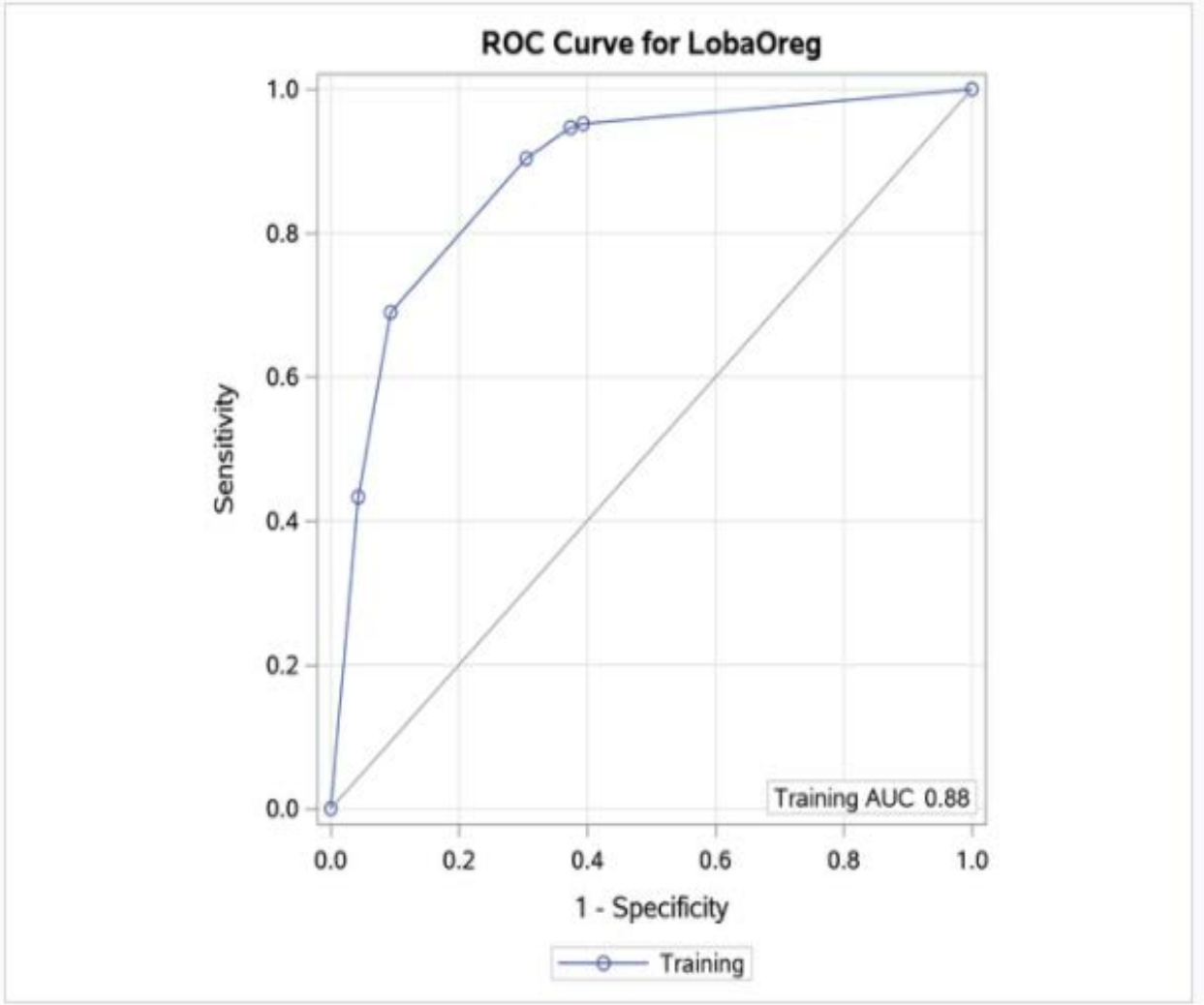
- Contrast this occupancy percentage with the 2.22% for the sites for which MinMinTemp –4.188.

- In summary, based on the first three splits, Lobaria oregana is most likely to be found at sites for which MinMinTemp –4.188, Aconif 81.896, and PrecipAve 167.922.

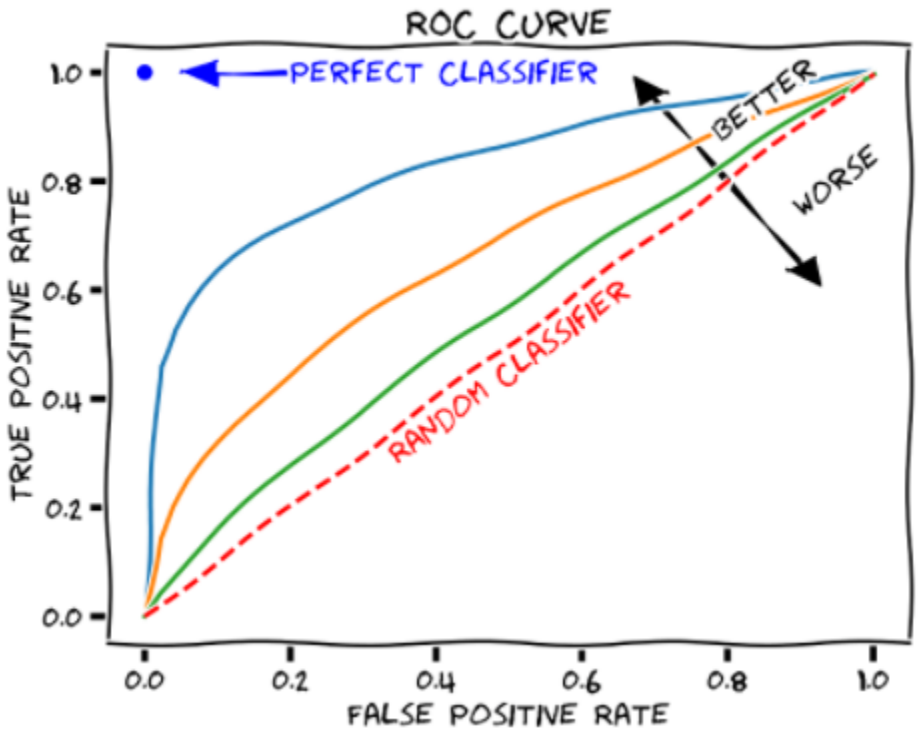


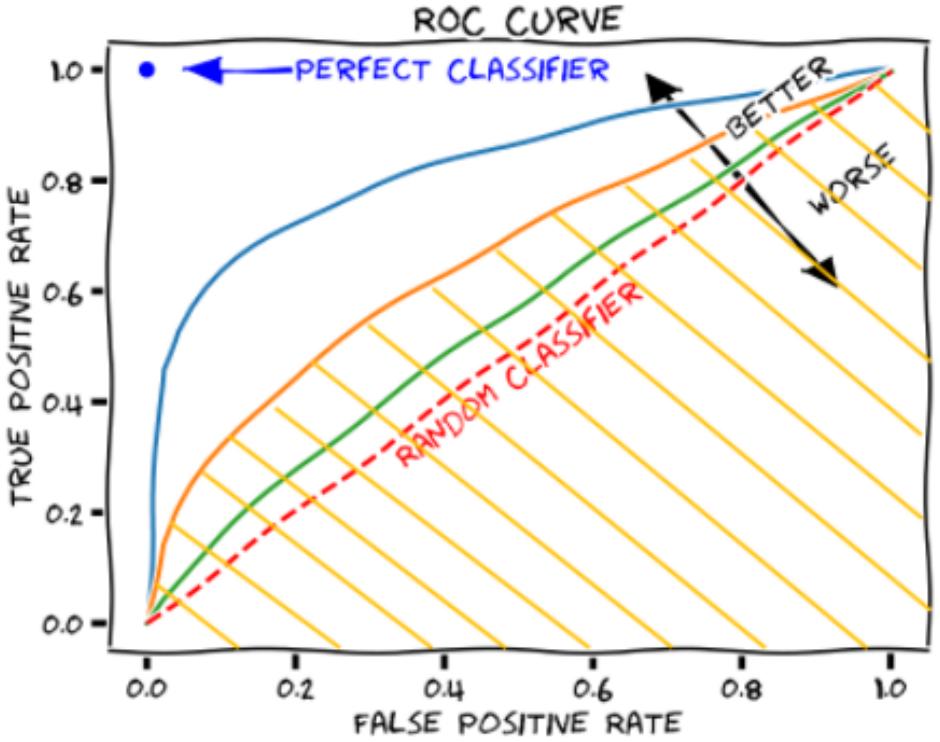
ROC CURVE FOR CLASSIFICATION

- The AUC statistic and the values of the ROC curve are computed from the training data. When you specify a validation data set by using the **PARTITION statement**, the plot displays an **additional ROC curve and AUC statistic**, whose values are computed from the validation data.
- Note: In this example, the computations of the sensitivity, specificity, AUC, and values of the ROC curve depend on defining LobaOreg=1 as the event of interest by using the EVENT= option in the MODEL statement.
- 진단의 관점에서 **민감도(sensitivity)**는 질병이 있는 사람을 얼마나 잘 찾아 내는가에 대한 값이고 특이도(**specificity**)는 정상을 얼마나 잘 찾아 내는가에 대한 값이다.



ROC CURVE INTERPRETATION





The colored area is AUC (정확성 지표)

REFERENCE

- https://documentation.sas.com/doc/ko/pgmsascdc/9.4_3.4/stathpug/stathpug_hpsplit_examples01.htm
- https://m.blog.naver.com/sharp_kiss/221826800044
- https://codedragon.tistory.com/9618
- https://www.sas.com/content/dam/SAS/en_ca/User%20Group%20Presentations/Toronto-Data-Mining-Forum/dzieciolowski-randomforests.pdf
- https://towardsdatascience.com/how-to-find-decision-tree-depth-via-cross-validation-2bf143f0f3d6

RANDOM FOREST PROCESS

Output 15.1.7: Fit Statistics for Classification of LAQ

Fit Statistics for Selected Tree									
	N Leaves	ASE	Mis-class	Sensitivity	Specificity	Entropy	Gini	RSS	AUC
Model Based	6	0.1046	0.1417	0.6898	0.9066	0.4825	0.2093	175.8	0.8805
Cross Validation	6	0.1236	0.1914	0.5668	0.8744				

- The model-based **misclassification rate** is low (14.2%), but the corresponding **sensitivity,** which measures the prediction accuracy at sites where the species is present, is only 69%.
- **Good overall** prediction **accuracy** but **poor prediction** of a **particular level** can occur when the data are not well balanced

FIT STATISTICS FOR THE SELECTED CLASSIFICATION TREE.

Output 15.1.7: Fit Statistics for Classification of LAQ

Fit Statistics for Selected Tree									
	N Leaves	ASE	Mis-class	Sensitivity	Specificity	Entropy	Gini	RSS	AUC
Model Based	6	0.1046	0.1417	0.6898	0.9066	0.4825	0.2093	175.8	0.8805
Cross Validation	6	0.1236	0.1914	0.5668	0.8744				

- Two sets of fit statistics are provided. The first is based on the **fitted model**, and the second (requested by the **CVMODELFIT** option) is based on 10-fold cross validation.

THE 'ACCURACY ' OF THE SELECTED CLASSIFICATION TREE

- The cross validation confusion matrix is produced when you specify the **CVMODELFIT option**. It is based on a 10-fold cross validation that is done independently of the 10-fold cross validation that is used to estimate ASEs for pruning parameters.

Output 15.1.6: Confusion Matrices for Classification of LAQ

The HPSPLIT Procedure

Confusion Matrices

	Actual	Predicted 0	Predicted 1	Error Rate
Model Based	0	592	61	0.0934
	1	58	129	0.3102
Cross Validation	0	571	82	0.1256
	1	81	106	0.4332

- K-겹 교차 검증(K-fold Cross Validation)은 가지고 있는 데이터를 K개의 그룹으로 나누어 그 그룹 중에서 하나를 추출하여 validation set으로 사용하는 것입니다. 그리고 이 과정을 K번 반복하여 나온 결과값을 평균내어 검증 결과 값으로 사용합니다.

TRAINING VS VALIDATION

- Cross validation