# Spatial prediction of landslide susceptibility in Taleghan basin, Iran

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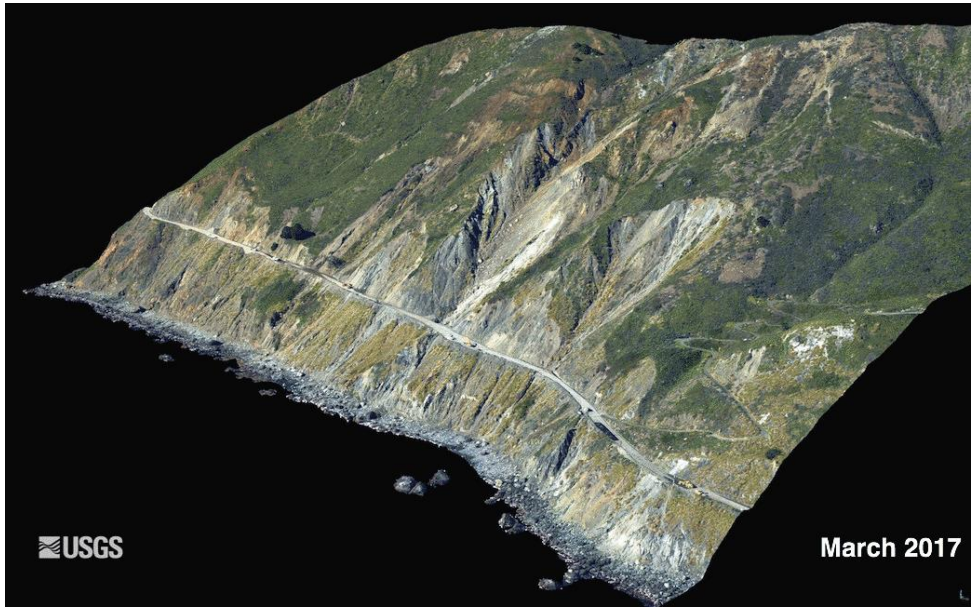
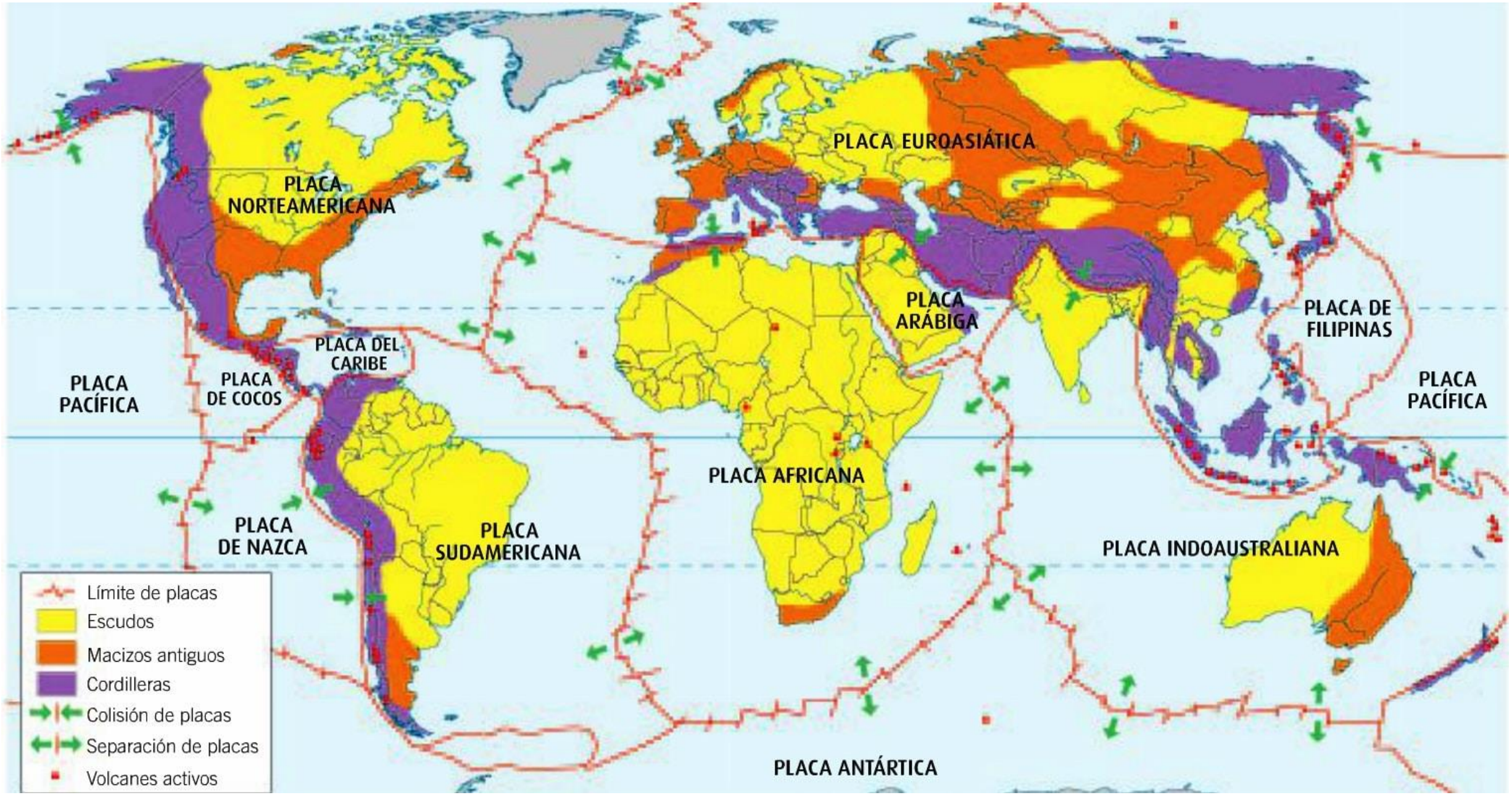
Geógrafa, Ma. SR e Geoprocessamento,

Doutoranda em Sensoriamento Remoto

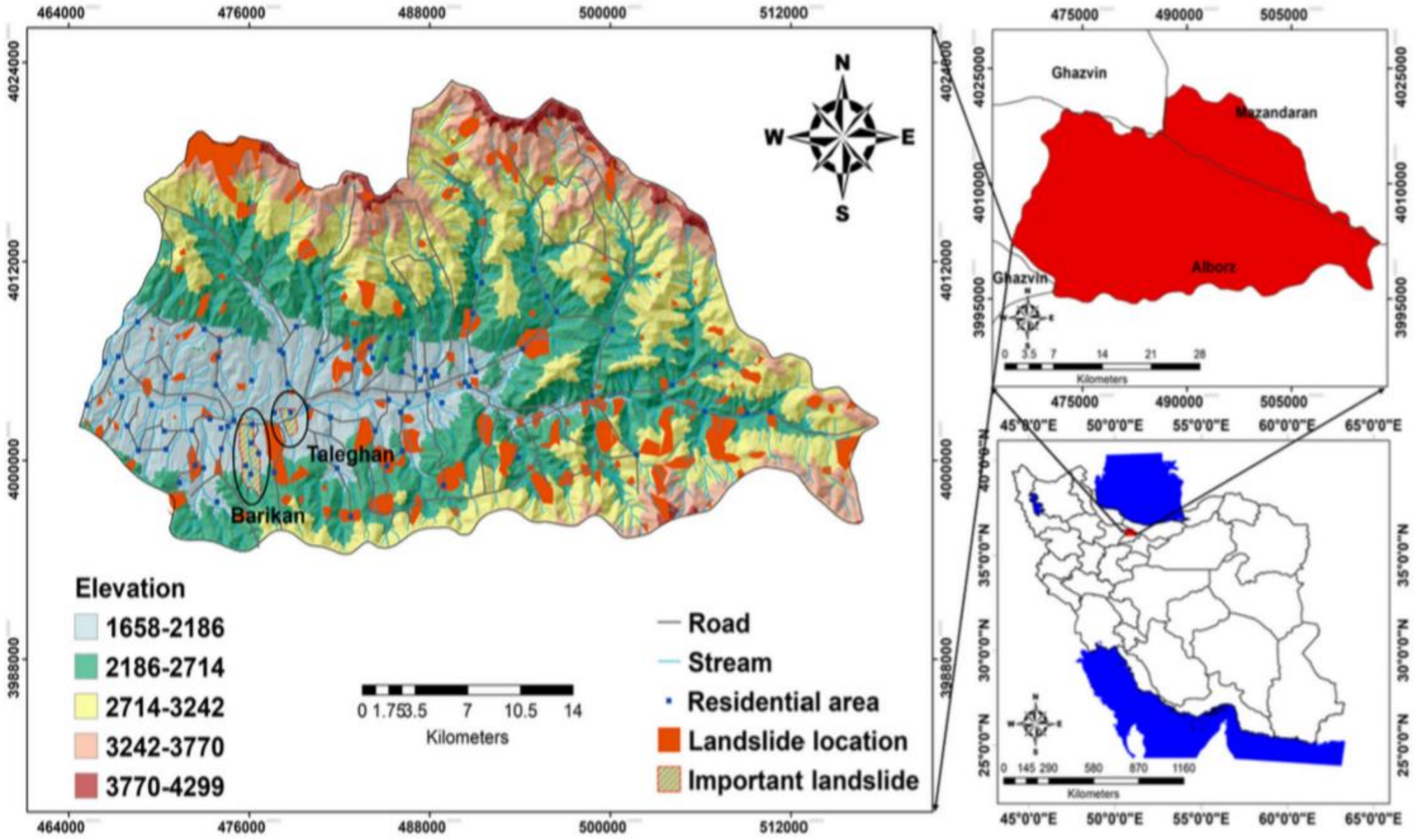
# Deslizamentos *(Landslides)*

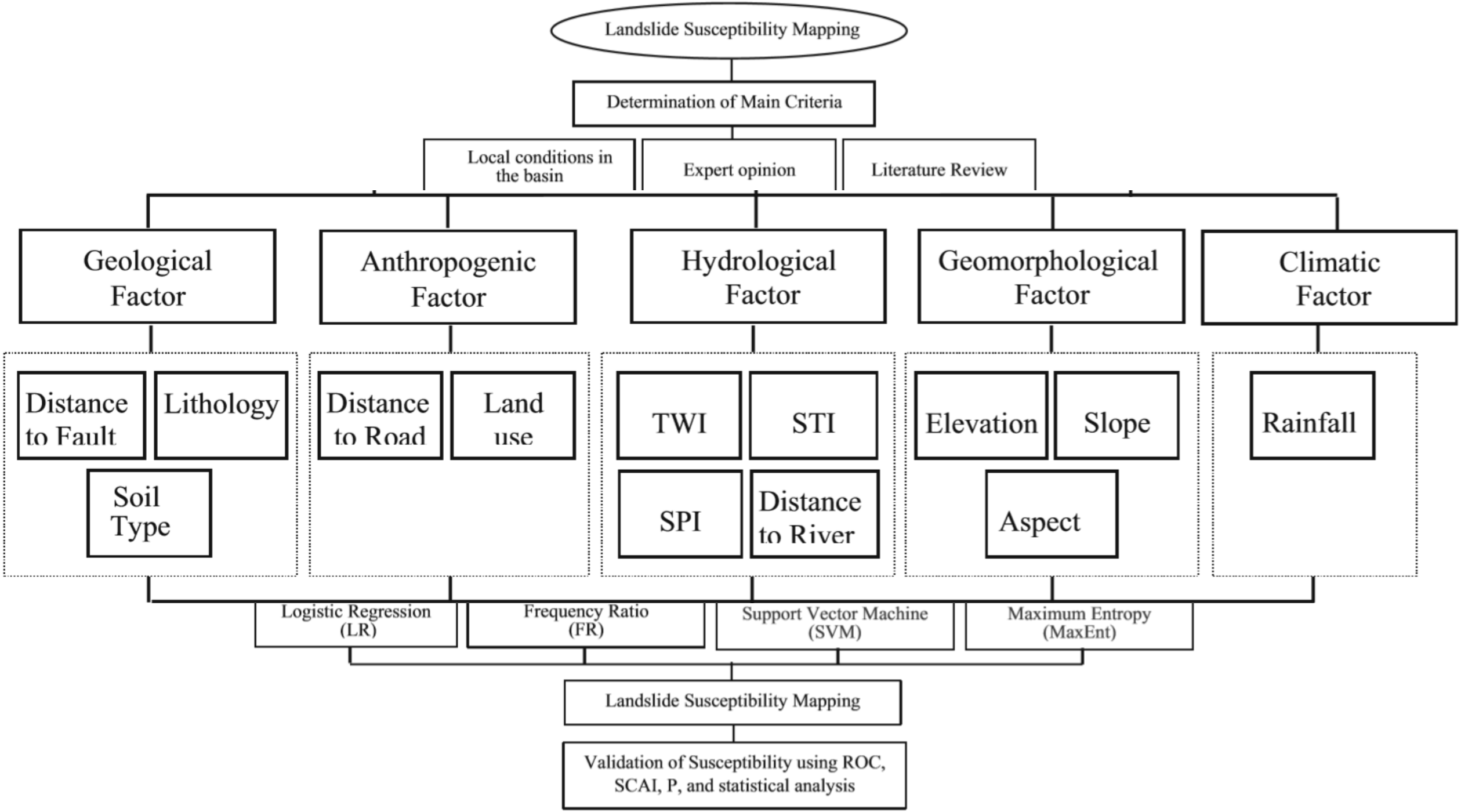



- Movimento rápido descente de materiais da encosta;
- Importância do mapeamento de suscetibilidade;
- Fenômenos frequentes no Irã.




Fonte: *https://magicanaturaleza.com/c-sismos/placas-tectonicas/*


464000
476000
488000
500000
512000
4024000
4012000
4000000
3988000
N
W
E
S
Taleghan
Barikan
Elevation
1658-2186
2186-2714
2714-3242
3242-3770
3770-4299
0 1.753.5 7 10.5 14
Kilometers
Road
Stream
Residential area
Landslide location
Important landslide
475000
490000
505000
4025000
4010000
3995000
Ghazvin
Mazandaran
Alborz
Ghazvin
0 3.5 7 14 21 28
Kilometers
45°0'0"E
50°0'0"E
55°0'0"E
60°0'0"E
65°0'0"E
40°0'0"N
35°0'0"N
30°0'0"N
25°0'0"N
0 145 290 580 870 1160
Kilometers


Landslide Susceptibility Mapping
Determination of Main Criteria
Local conditions in the basin
Expert opinion
Literature Review
Geological Factor
Anthropogenic Factor
Hydrological Factor
Geomorphological Factor
Climatic Factor
Distance to Fault
Lithology
Soil Type
Distance to Road
Land use
TWI
STI
SPI
Distance to River
Elevation
Slope
Aspect
Rainfall
Logistic Regression (LR)
Frequency Ratio (FR)
Support Vector Machine (SVM)
Maximum Entropy (MaxEnt)
Landslide Susceptibility Mapping
Validation of Susceptibility using ROC, SCAI, P, and statistical analysis

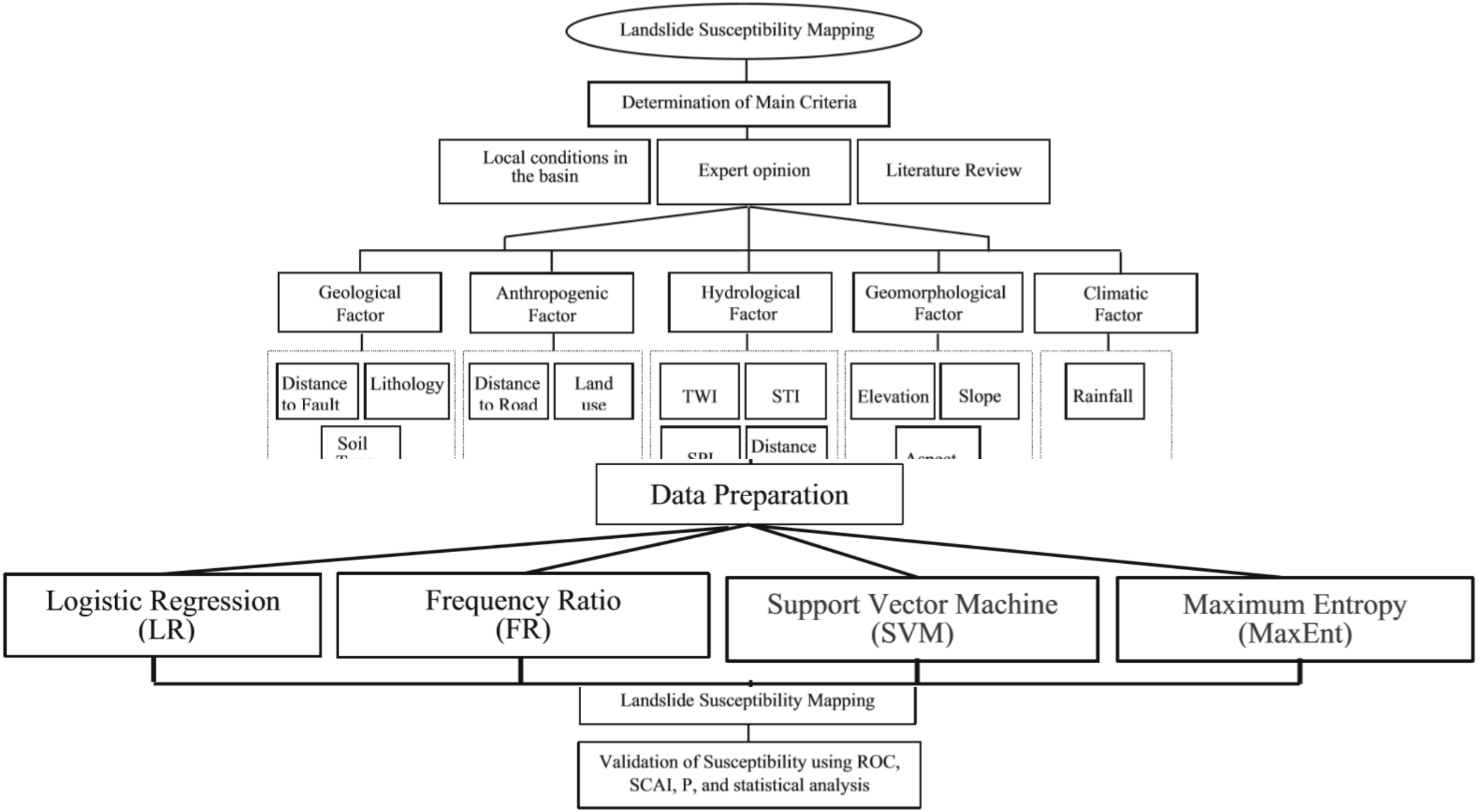
# Atributos Preditivos

Alta correlação:

- TOLs < 0.1
- VIFs > 10

**Table 2** Multicollinearity analysis of landslide conditioning factors

| No. | Landslide conditioning factor | TOL | VIF |
|---|---|---|---|
| 1 | Land use | 0.944 | 1.059 |
| 2 | Lithology | 0.812 | 1.232 |
| 3 | Soil texture | 0.917 | 1.090 |
| 4 | Precipitation | 0.735 | 1.360 |
| 5 | Slope degree | 0.801 | 1.249 |
| 6 | Slope aspect | 0.910 | 1.099 |
| 7 | Elevation | 0.946 | 1.057 |
| 8 | Distance to fault | 0.828 | 1.208 |
| 9 | Distance to stream | 0.903 | 1.107 |
| 10 | Distance to road | 0.877 | 1.141 |
| 11 | STI | 0.727 | 1.376 |
| 12 | SPI | 0.902 | 1.109 |
| 13 | TWI | 0.736 | 1.360 |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Data Preparation
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# Avaliação de Desempenho dos Modelos

- *Area Under Curve* (AUC);
- *Seed Cell Area Index* (SCAI);
- *P Index*;
- Análises estatísticas: Sensibilidade, Especificidade e Acurácia.

# Resultados

- Regressão Logística

**Table 3** Coefficients obtained by the logistic regression model

| Variable | B | S.E. | Wald | *df* | Sig. | Exp (B) |
|---|---|---|---|---|---|---|
| Distance to road | − 0.174 | 0.113 | 2.017 | 1 | 0.043 | 0.816 |
| Distance t stream | − 1.689 | 0.224 | 57.062 | 1 | 0.000 | 0.185 |
| Land use | 0.854 | 0.160 | 27.662 | 1 | 0.000 | 2.325 |
| TWI | 0.525 | 0.236 | 4.967 | 1 | 0.026 | 1.691 |
| STI | − 0.018 | 0.025 | 0.056 | 1 | 0.047 | 0.085 |
| Elevation | − 0.842 | 0.156 | 29.795 | 1 | 0.000 | 0.427 |
| Lithology | 1.993 | 0.343 | 33.824 | 1 | 0.000 | 7.335 |
| Slope | − 0.981 | 0.233 | 17.742 | 1 | 0.000 | 0.375 |
| Soil texture | 1.156 | 0.254 | 20.691 | 1 | 0.000 | 0.315 |
| Slope aspect | − 0.560 | 0.179 | 9.841 | 1 | 0.002 | 0.571 |
| Distance to fault | 0.337 | 0.126 | 7.175 | 1 | 0.007 | 0.714 |
| SPI | 0.009 | 0.016 | 0.0276 | 1 | 0.049 | 0.076 |
| Precipitation | − 0.937 | 0.231 | 16.467 | 1 | 0.000 | 0.392 |
| Constant | 1.406 | 0.339 | 17.184 | 1 | 0.000 | 4.079 |

# Resultados

*Frequency Ratio*

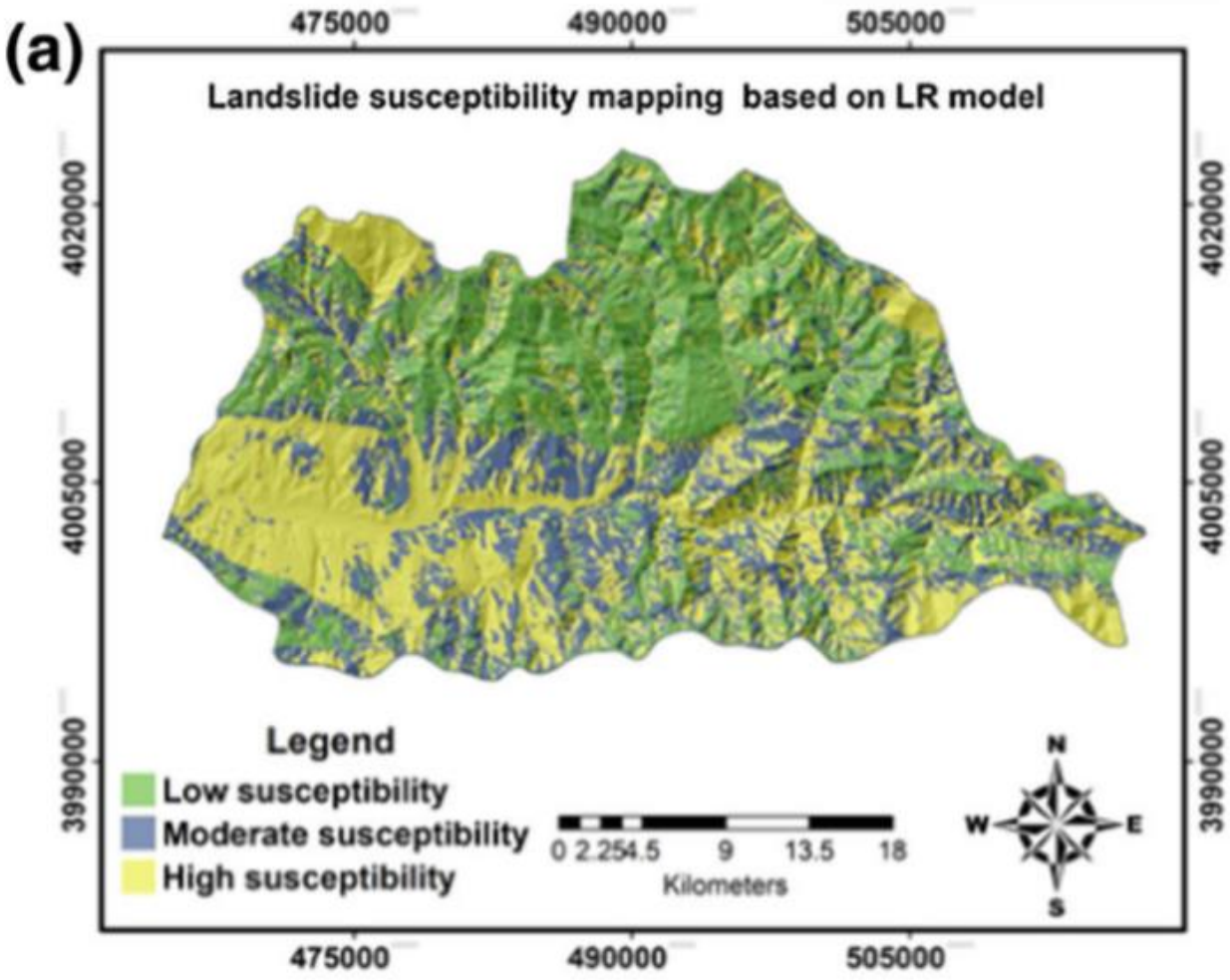
- Textura do solo: argila;
- Litologia: resistência relativamente baixa;
- Distância de falhas: < 3000 m;
- Altitude: entre 3.770 e 4299 m.

# Resultados

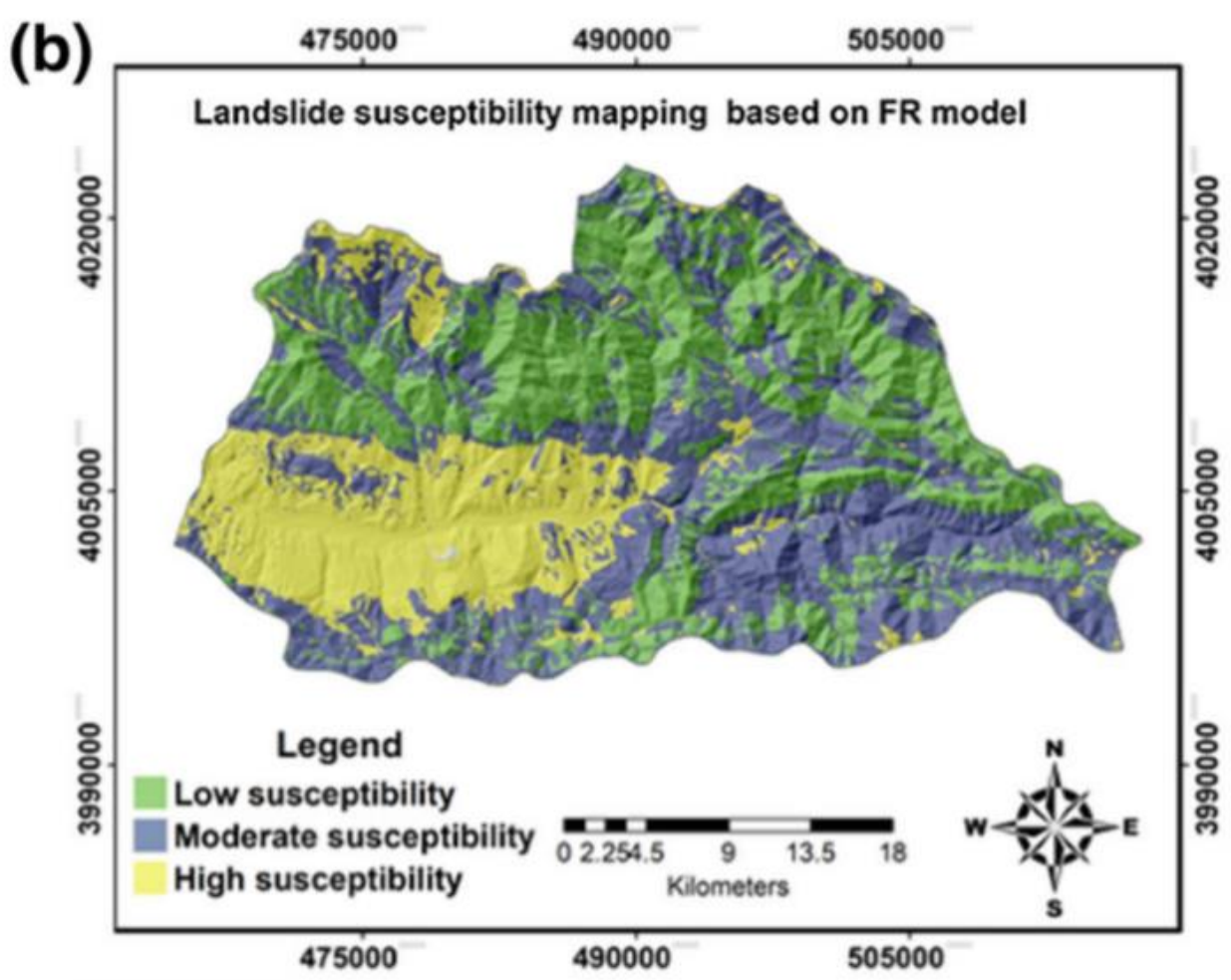
- *Maximum Entropy*

**Table 7** Analysis of the contribution of the variables

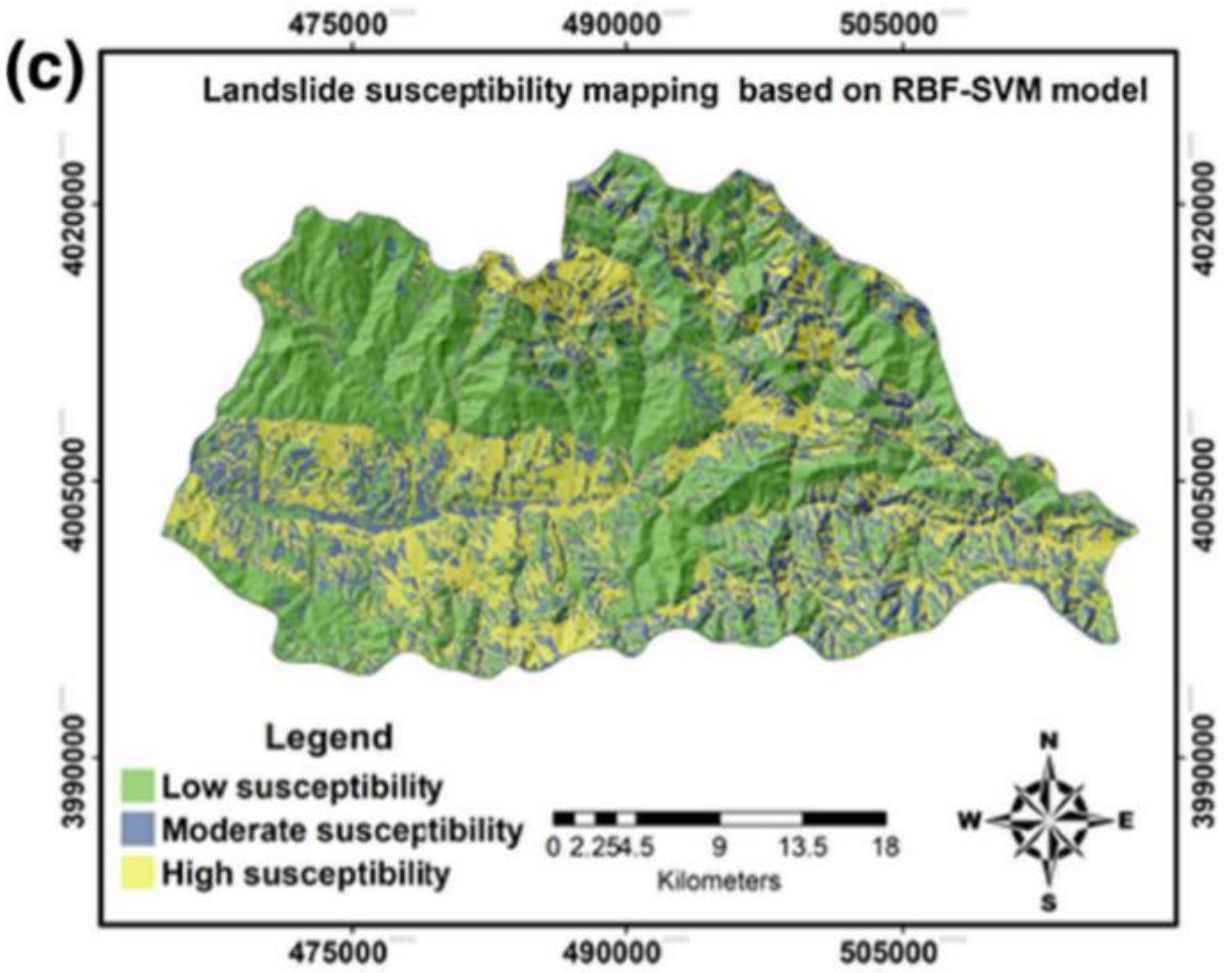
| No. | Variable | Percent contribution | No. | Variable | Percent contribution |
|---|---|---|---|---|---|
| 1 | Elevation contribution | 2.61 | 8 | Slope aspect contribution | 7.88 |
| 2 | Stream contribution | 15.47 | 9 | Slope contribution | 17.54 |
| 3 | SPI contribution | 0.19 | 10 | Fault contribution | 1.47 |
| 4 | Lithology contribution | 25.21 | 11 | TWI contribution | 0.41 |
| 5 | Land use contribution | 5.82 | 12 | STI contribution | 0.37 |
| 6 | Soil texture contribution | 11.90 | 13 | Road contribution | 1.18 |
| 7 | Precipitation contribution | 9.94 | | | |



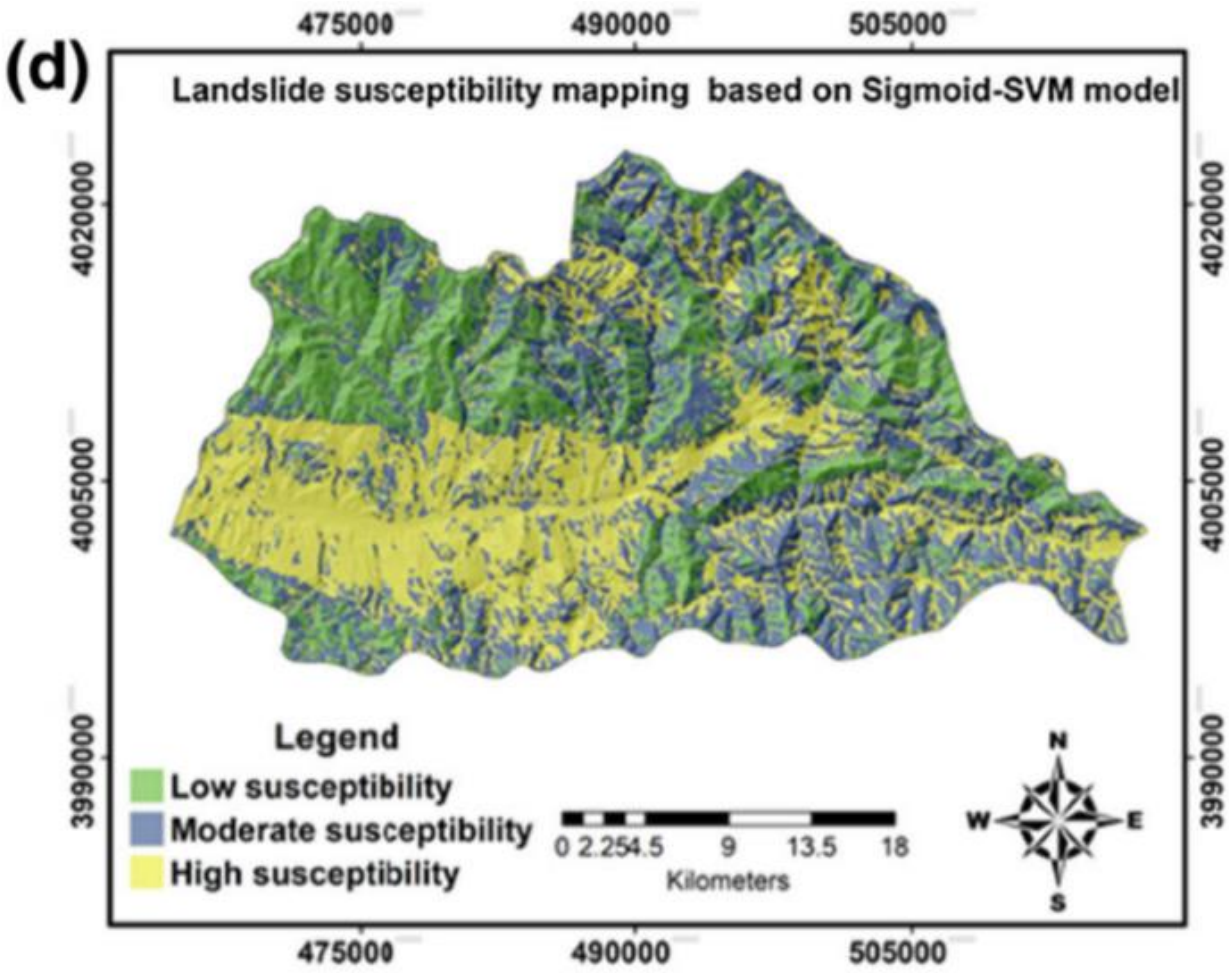

Regressão Logística



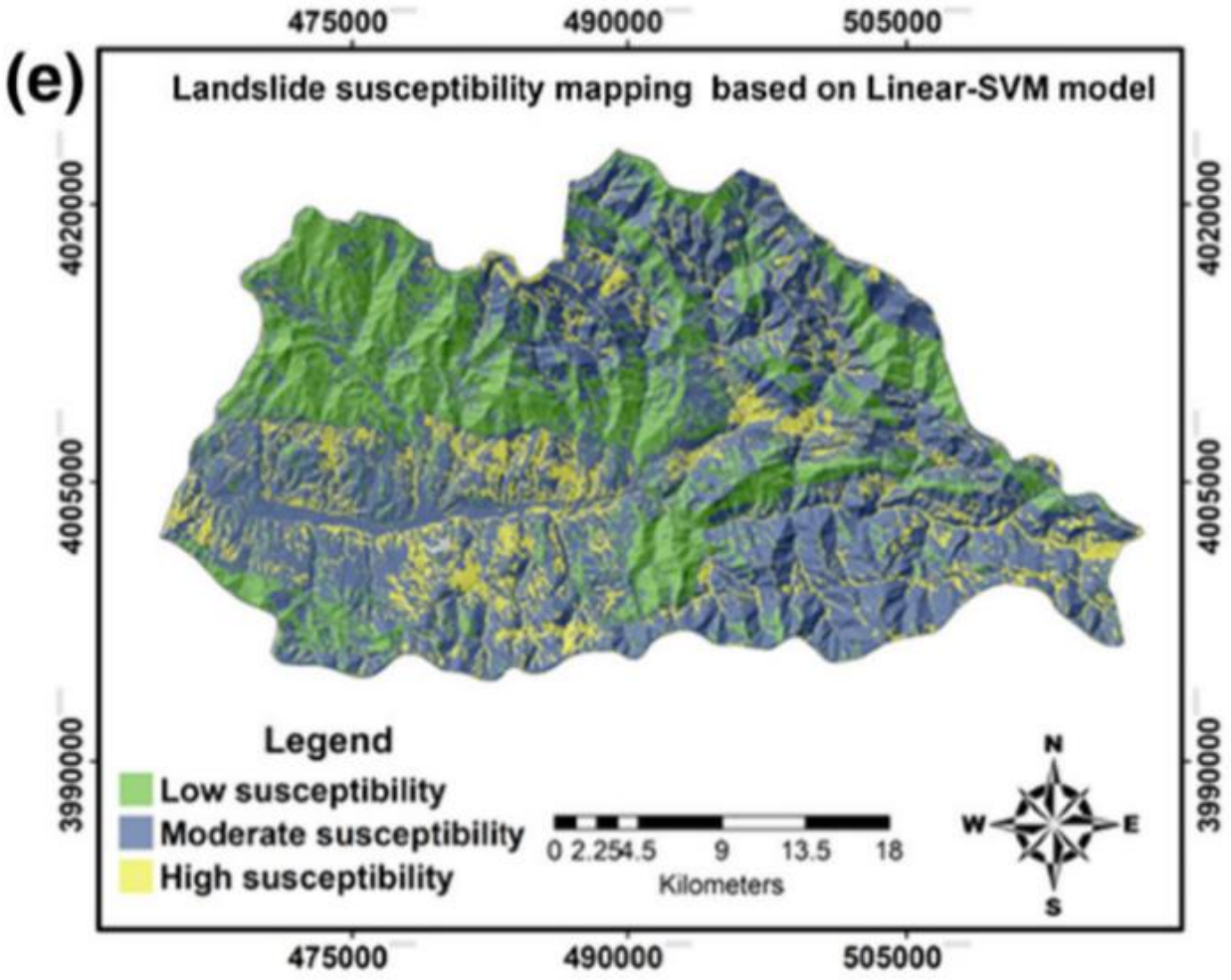

*Frequency Ratio*



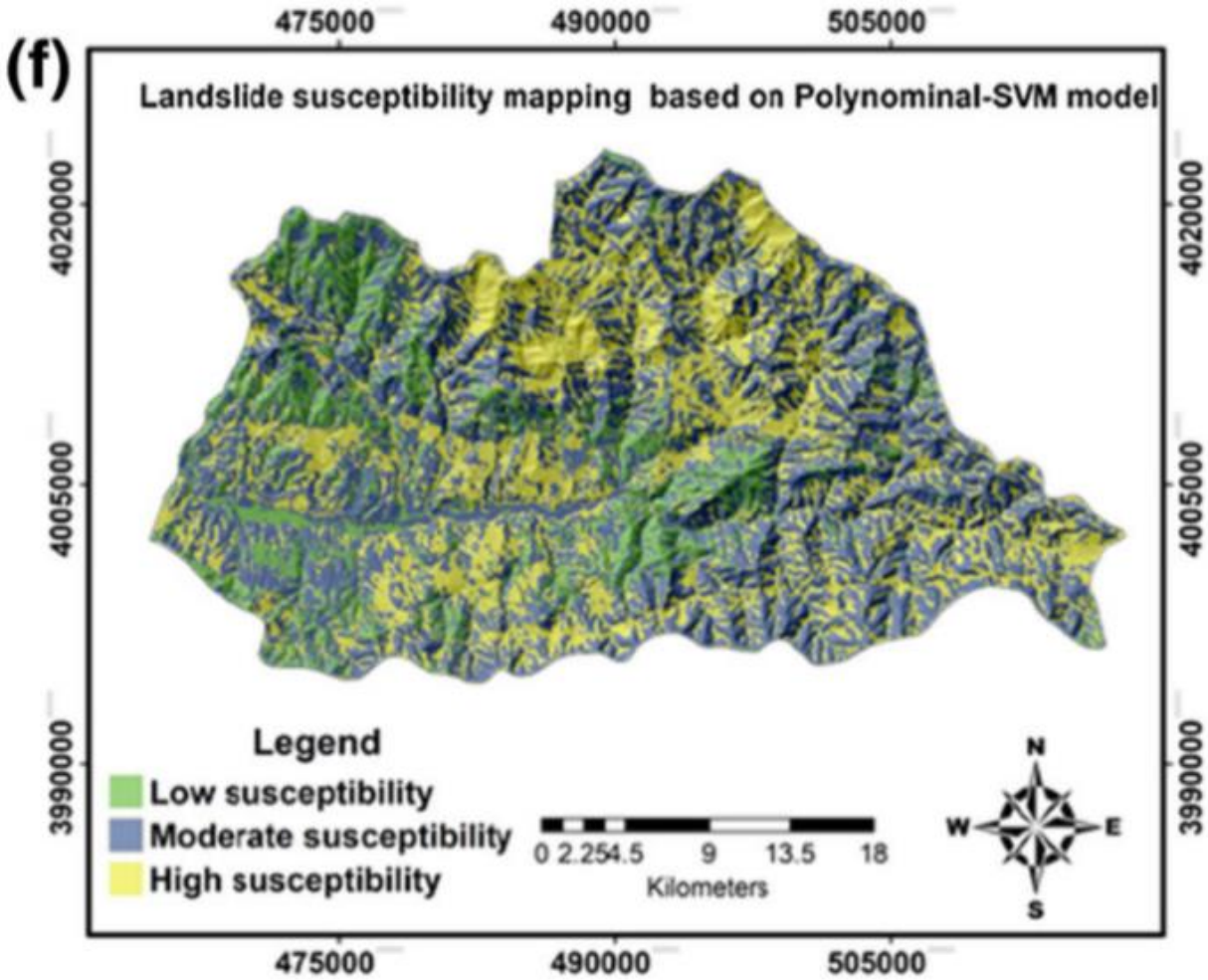

SVM – *Radial base function*



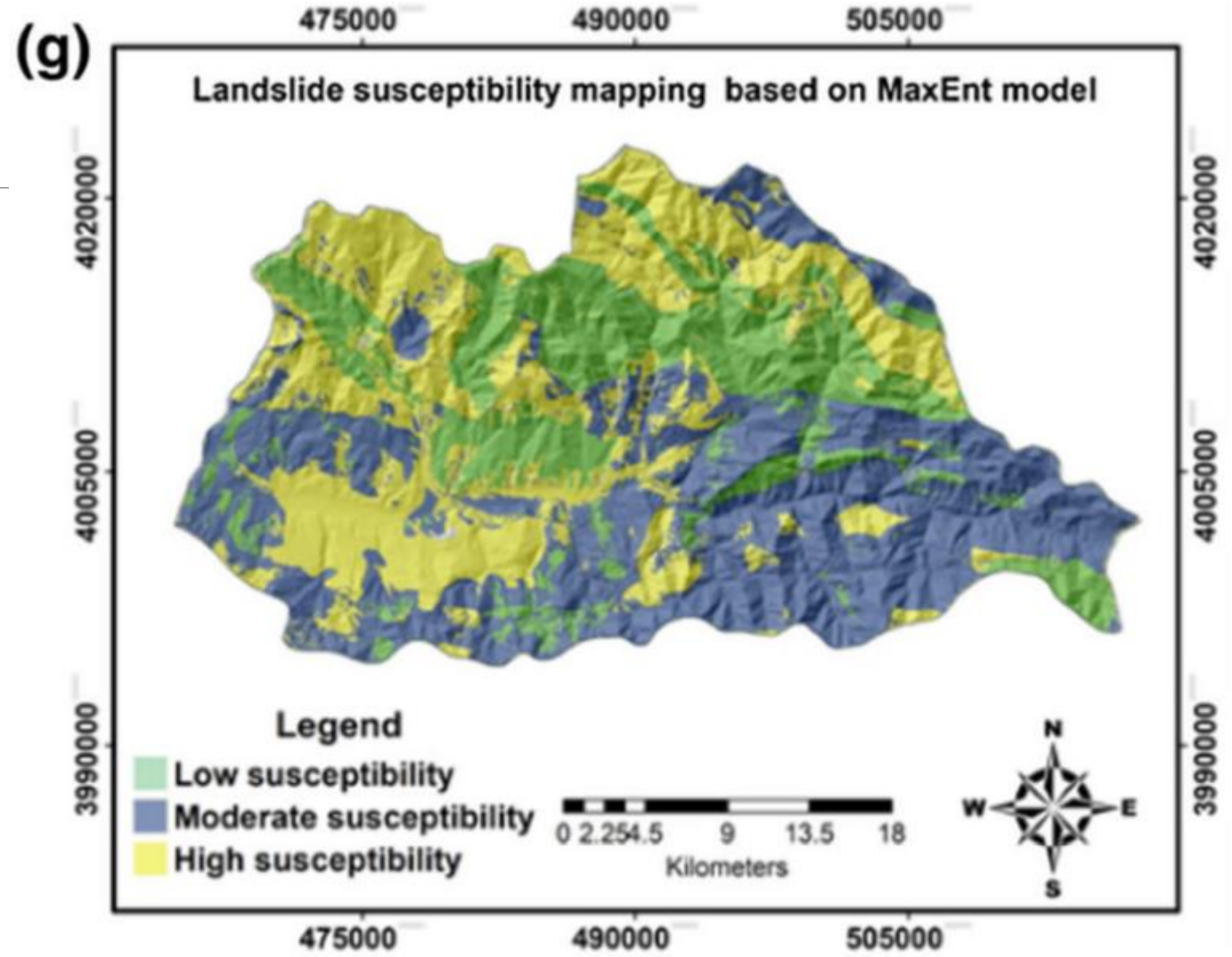

SVM - *Sigmoid*




SVM - *Linear*

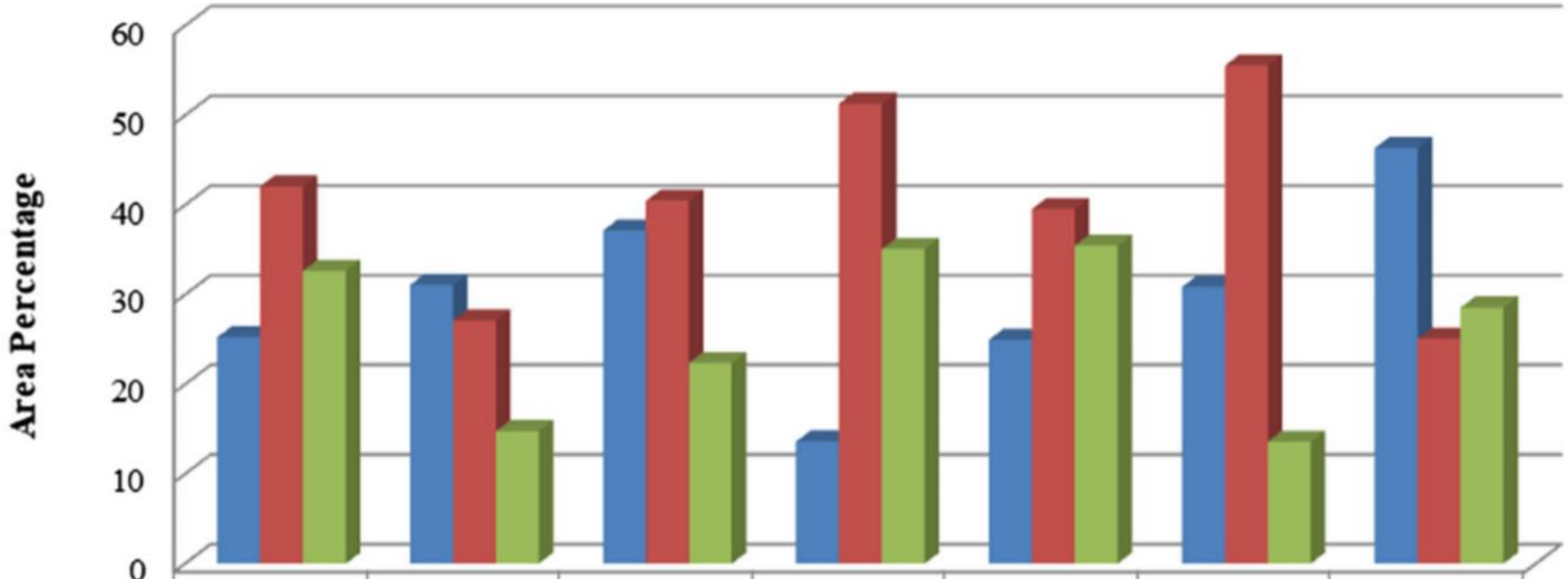



SVM - *Polynomial*




*Maximum Entropy*

# Resultados




| | MaxEnt | LR | FR | PL-SVM | SIG-SVM | LN-SVM | RBF-SVM |
|---|---|---|---|---|---|---|---|
| Low | 25.26 | 31.11 | 37.15 | 13.62 | 24.97 | 30.86 | 46.37 |
| Moderate | 42.08 | 27.12 | 40.47 | 51.3 | 39.56 | 55.56 | 25.07 |
| High | 32.66 | 14.77 | 22.38 | 35.08 | 35.47 | 13.59 | 28.56 |

# Resultados

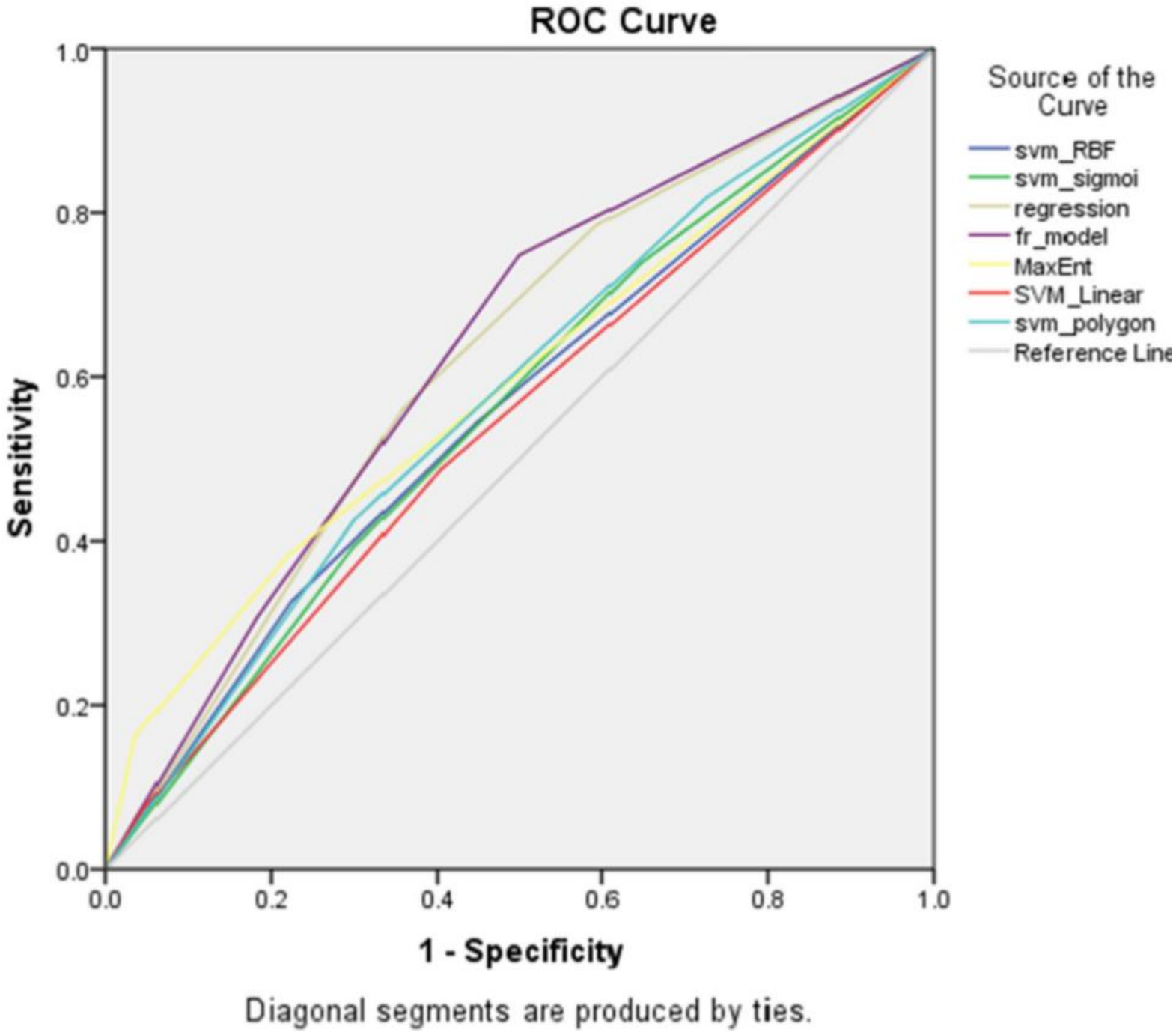
**Table 8** AUC value of the ROC curve in a random sample of landslide susceptibility zoning

| Landslide susceptibility zoning method | Area | Std. error[a] | Asymptotic sig.[b] | Asymptotic 95% confidence interval | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| RBF-SVM | 0.660 | 0.015 | 0.000 | 0.631 | 0.69 |
| SIG-SVM | 0.663 | 0.015 | 0.000 | 0.633 | 0.69 |
| LR | 0.807 | 0.015 | 0.000 | 0.785 | 0.83 |
| FR | 0.732 | 0.015 | 0.000 | 0.704 | 0.76 |
| MaxEnt | 0.812 | 0.014 | 0.000 | 0.764 | 0.86 |
| LN-SVM | 0.643 | 0.015 | 0.003 | 0.616 | 0.67 |
| PL-SVM | 0.679 | 0.015 | 0.000 | 0.649 | 0.71 |

[a]Under a nonparametric assumption

[b]Null hypothesis: true area = 0.5

# Resultados


ROC Curve
Sensitivity
1 - Specificity
0.0
0.2
0.4
0.6
0.8
1.0
Source of the Curve
svm_RBF
svm_sigmoi
regression
fr_model
MaxEnt
SVM_Linear
svm_polygon
Reference Line
Diagonal segments are produced by ties.

# Resultados

**Table 9** Landslide densities of the landslide-susceptible categories for all methods

| Susceptibility category | MaxEnt | | | LR | | | FR | | | PL-SVM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | SCAI | a | b | SCAI | a | b | SCAI | a | b | SCAI |
| Low | 25.26 | 5.78 | 4.36 | 31.11 | 11.35 | 3.27 | 37.15 | 11.73 | 2.65 | 13.62 | 12.23 | 1.11 |
| Moderate | 42.08 | 43.87 | 0.96 | 27.12 | 43.97 | 0.92 | 40.47 | 30.35 | 0.89 | 51.30 | 45.99 | 1.12 |
| High | 32.66 | 50.35 | 0.65 | 41.77 | 44.68 | 0.50 | 22.38 | 57.92 | 0.72 | 35.08 | 41.78 | 0.84 |

| Susceptibility category | SIG-SVM | | | LN-SVM | | | RBF-SVM | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | SCAI | a | b | SCAI | a | b | SCAI |
| Low | 24.97 | 15.37 | 1.62 | 30.86 | 19.43 | 1.59 | 46.37 | 35.09 | 1.32 |
| Moderate | 39.56 | 34.28 | 1.15 | 55.56 | 56.78 | 0.98 | 25.07 | 25.09 | 1.01 |
| High | 35.47 | 5035 | 0.70 | 13.59 | 23.79 | 0.57 | 28.56 | 39.82 | 0.71 |

a: % area of the susceptibility class

b: % landslide in each susceptibility class (or seed %)

# Resultados

**Table 10** Precision of the predicted results

| Landslide susceptibility zoning method | $K_s$ ($km^2$) | S ($km^2$) | P |
|---|---|---|---|
| MaxEnt | 104.46 | 110.87 | 0.942 |
| LR | 98.17 | | 0.886 |
| FR | 97.28 | | 0.883 |
| SIG-SVM | 93.84 | | 0.846 |
| LN-SVM | 89.32 | | 0.806 |
| RBF-SVM | 71.96 | | 0.649 |
| PL-SVM | 97.31 | | 0.878 |

**Table 12** Model performance

| No. | Parameters | MaxEnt | LR | FR | PL-SVM | SIG-SVM | LN-SVM | RBF-SVM |
|---|---|---|---|---|---|---|---|---|
| 1 | True positive | 243 | 241 | 216 | 211 | 206 | 191 | 192 |
| 2 | True negative | 199 | 183 | 191 | 177 | 170 | 122 | 174 |
| 3 | False positive | 79 | 95 | 87 | 101 | 108 | 156 | 104 |
| 4 | False negative | 35 | 37 | 62 | 67 | 72 | 87 | 86 |
| 5 | Sensitivity (%) | 87.40 | 86.70 | 77.70 | 75.90 | 74.10 | 68.70 | 69.10 |
| 6 | Specificity (%) | 71.60 | 65.80 | 68.70 | 63.70 | 61.20 | 43.90 | 62.60 |
| 7 | Accuracy (%) | 79.50 | 76.30 | 73.20 | 69.80 | 67.60 | 56.30 | 65.80 |

**Table 13** Model validation

| No. | Parameters | MaxEnt | LR | FR | PL-SVM | SIG-SVM | LN-SVM | RBF-SVM |
|---|---|---|---|---|---|---|---|---|
| 1 | True positive | 106 | 104 | 99 | 91 | 90 | 81 | 88 |
| 2 | True negative | 82 | 78 | 79 | 75 | 70 | 40 | 71 |
| 3 | False positive | 37 | 41 | 40 | 44 | 49 | 79 | 48 |
| 4 | False negative | 13 | 15 | 20 | 28 | 29 | 38 | 31 |
| 5 | Sensitivity (%) | 89.10 | 87.40 | 83.20 | 76.50 | 75.60 | 68.10 | 73.90 |
| 6 | Specificity (%) | 68.90 | 65.50 | 66.40 | 63.00 | 58.80 | 33.60 | 59.70 |
| 7 | Accuracy (%) | 79.00 | 76.50 | 74.80 | 69.70 | 67.20 | 50.80 | 66.80 |

# Conclusões

- Os atributos preditivos geológicos/litológicos apresentaram maior importância;

- *Maximum Entropy* e Regressão Logísticas foram os modelos que apresentaram melhores performances;

- *Frequency Ratio* é um modelo simples, que explora a correlação entre a ocorrência deslizamentos e as classes de cada atributo, podendo ser considerado o de maior parcimônia.

# Obrigada pela atenção!

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