

Digital Morphometry Applied to Geo-Hazard Risk Assessment: A Case Study from Germany

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1. Introduction – Overview, motivation & objectives
 2. Study area & data
 3. Methodology
 4. Results
 5. Conclusion

Overview

- The inclusion of **new DEM derived morphometric parameters** in an **Artificial Neural Network (ANN)** for the prediction of landslide susceptibility.
- Geomorphometry - the science of quantitative land surface analysis
- Landslide susceptibility - is the likelihood of a landslide occurring in an area on the basis of local terrain conditions
- Artificial Neural Network – computerized network programmed to mimic the neuron system of the human brain, using a combination of algorithms.

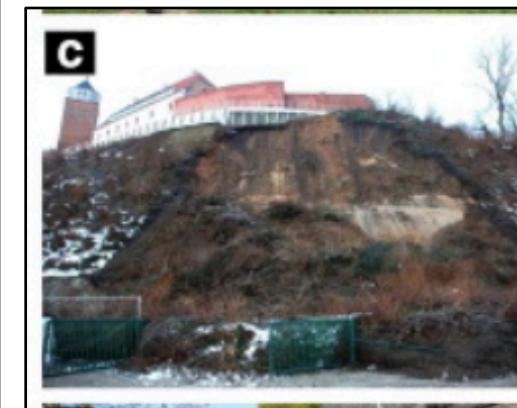
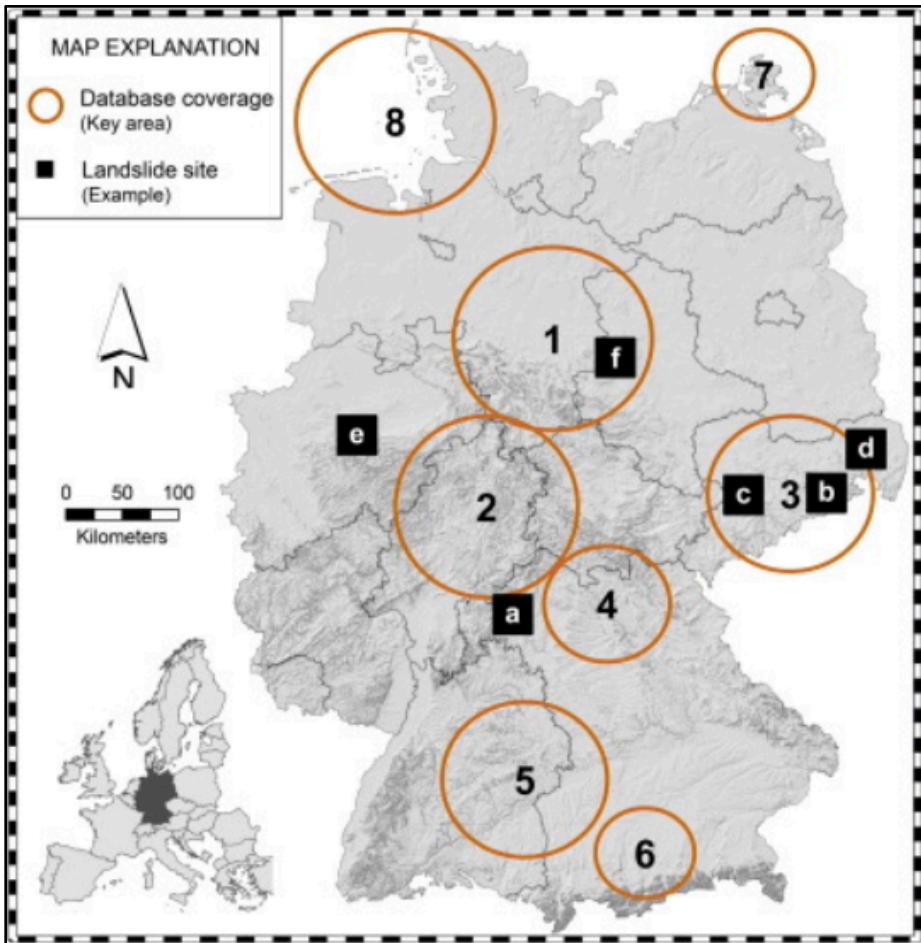
Motivation

- Geo-hazards such as landslides pose a **threat to infrastructure & livelihoods**.
- Increasing **human interaction & modification** of the landscape coupled with **climate change** put pressure on the natural terrain morphology, potentially causing destabilization in landslide susceptible zones.
- **German federal agencies** have been already begun the reassessment of evolving conditions due to climate change. The first step of this is the development of **landslide inventories and identification of vulnerable areas**.
- The availability of **new data extraction & modelling techniques** can expand the possibilities of parameters used to model this phenomena.

1. Introduction



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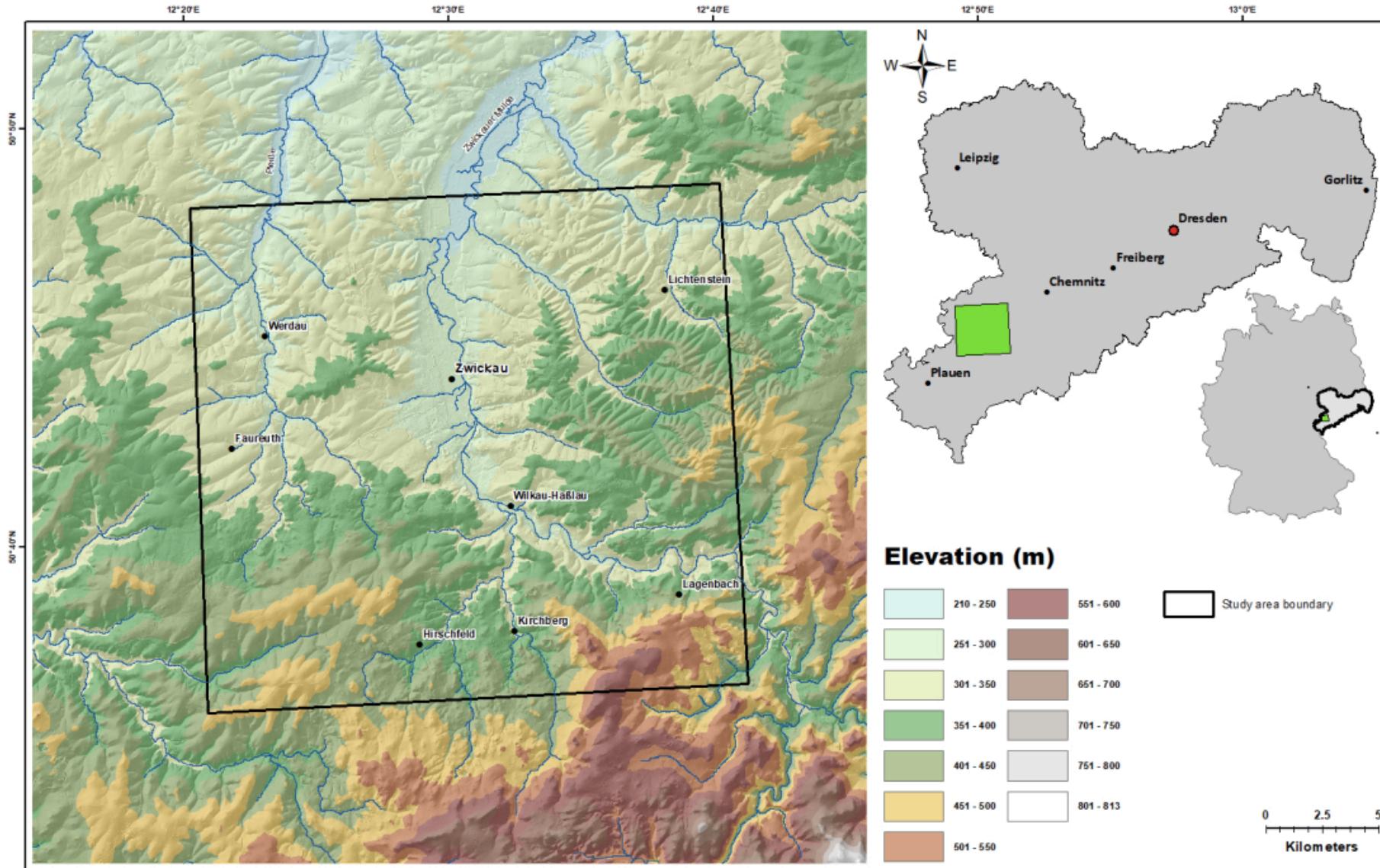


(b) rotational slide after intense rainfall at a road cut in Glashütte, Saxony, in the year 2002 (Photo by H. Weber, Cunnersdorf, Saxony); **(c)** 2011 Burgberg landslide caused by the collapse of a retaining wall at a cultural heritage site in Eilenburg, Saxony (Photo: Database B. Damm); **(d)** historic rockfall (year 1936) near Postelwitz-Schmilka, Saxony (Courtesy of P. Dommaschk, LfUG)

Main Objectives

- Assessment and development of **new** morphological parameters for landslide susceptibility modeling in ArcGIS.
 - Review of **parameters** available and their suitability, with a focus on tectonic parameters
 - Review of **methodologies** available
- Addition of the newly developed parameters within an Artificial Neural Network (ANN) for susceptibility modelling and assessment.
 - Validation of the model
 - Effective visualization of the results

2. Study area & Data

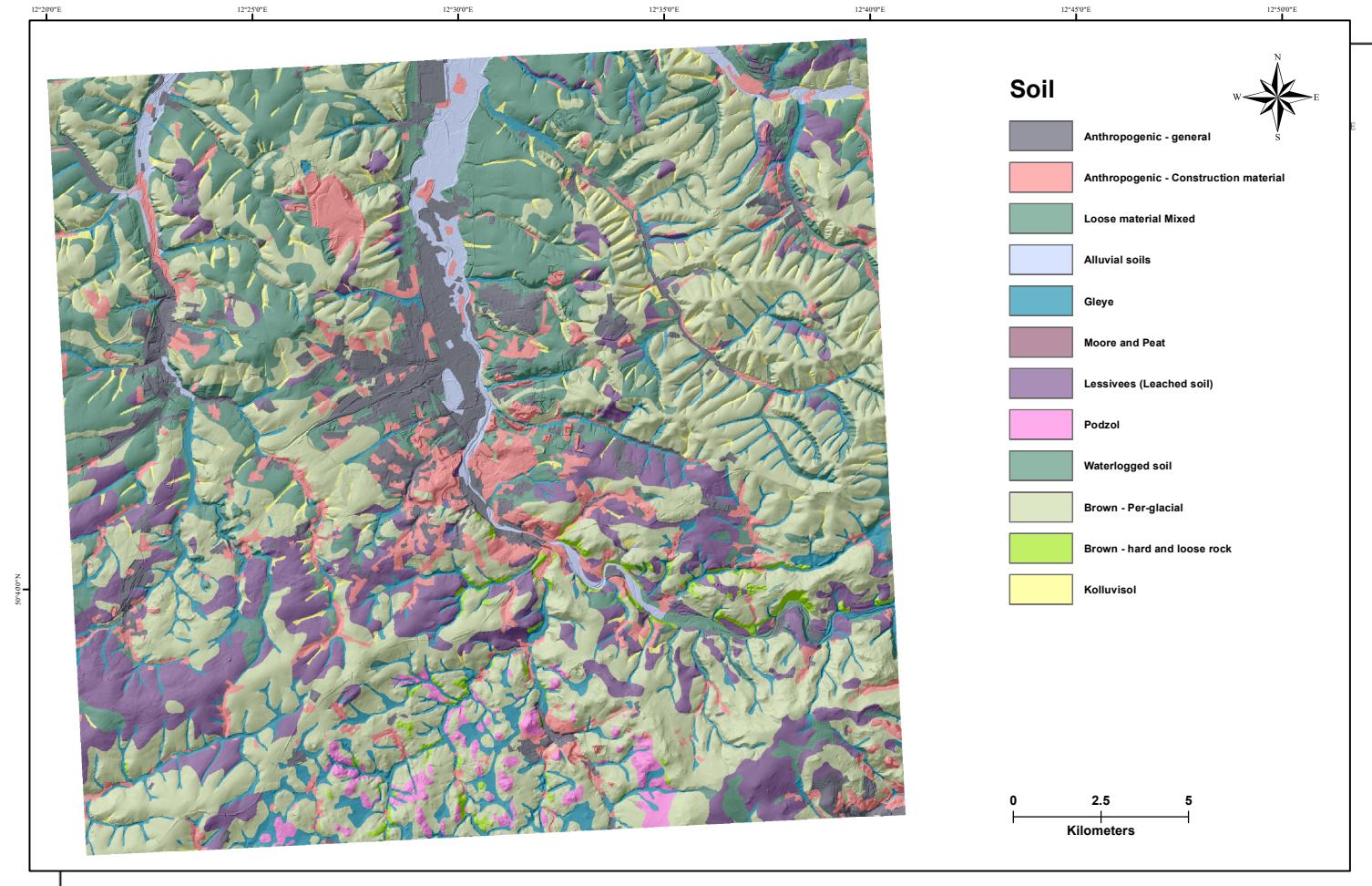


Study Area

- Area approx. 531km²
- Elevation Range: 235 – 605m
- District of Zwickau
- Two drainage basins
- Based on 4 geological maps
- Foreland of the Erzgebirge

Data Used

- DEM 10m resolution (AdV)
- Geological 1:25,000 map (LfULG)
- Soil 1:50,000 (LfULG)
- Landslide Inventory - 4 Points (LfULG)



Methodology Workflow – 4 stages

1. Pre-processing

2. Data Creation and tool development

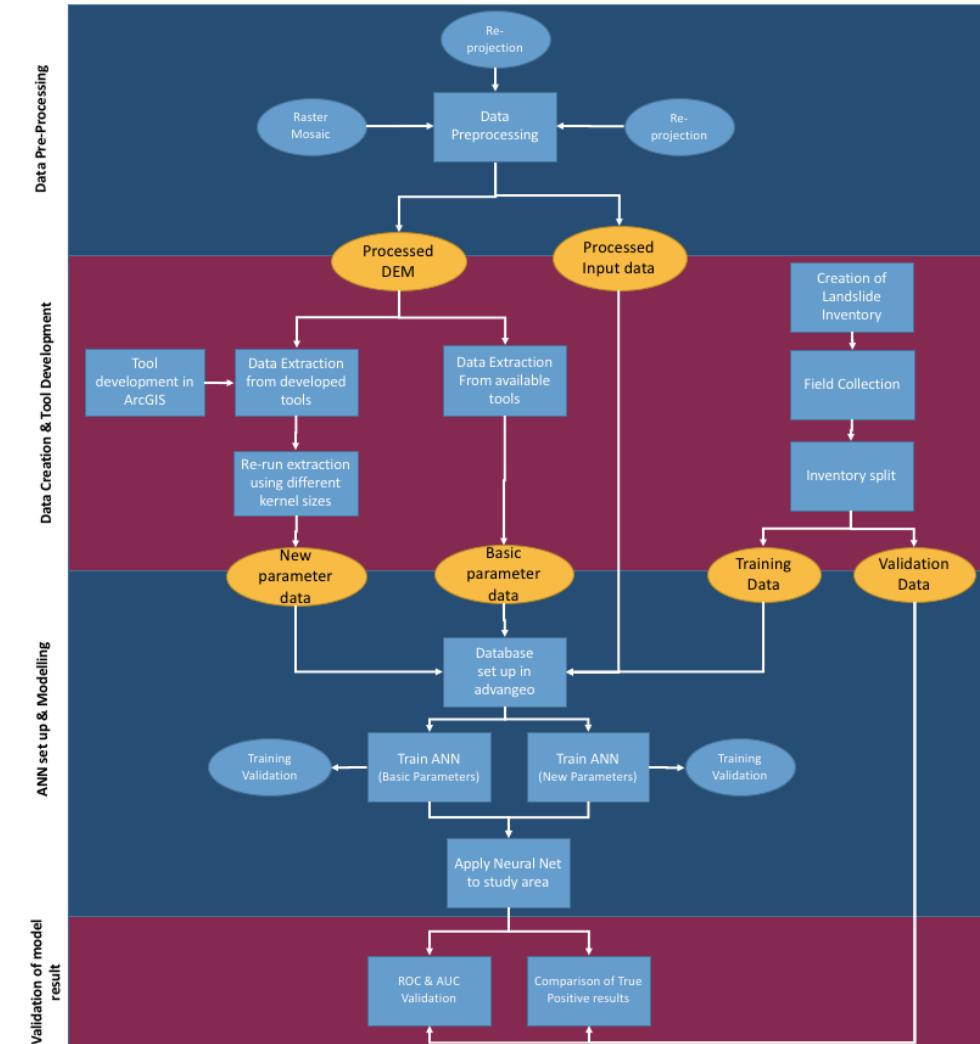
- Creation and division of landslide inventory
- Tool creation in ArcGIS
- Data extraction – developed and available tools (drainage net)
- Multiple kernel sizes run.

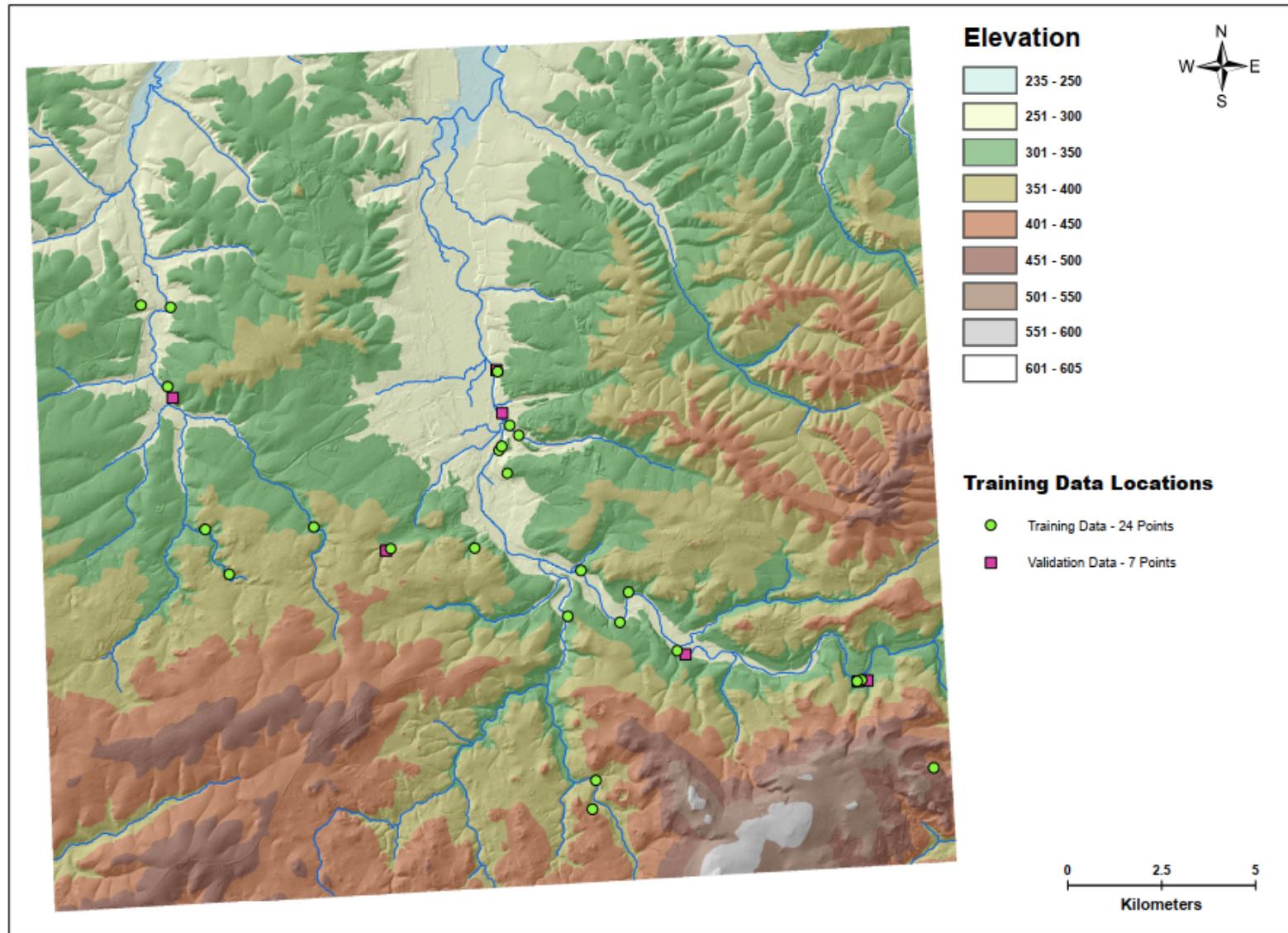
3. ANN set up and modelling using advangeo software

- ANN set up
- Training phase
- Application phase
- Five models created

4. Validation of model results

- True positive comparison
- ROC & AUC





Data Creation: inventory

Initial Inventory: 4 points

Field Collected: 29 points

Final inventory: 31 points

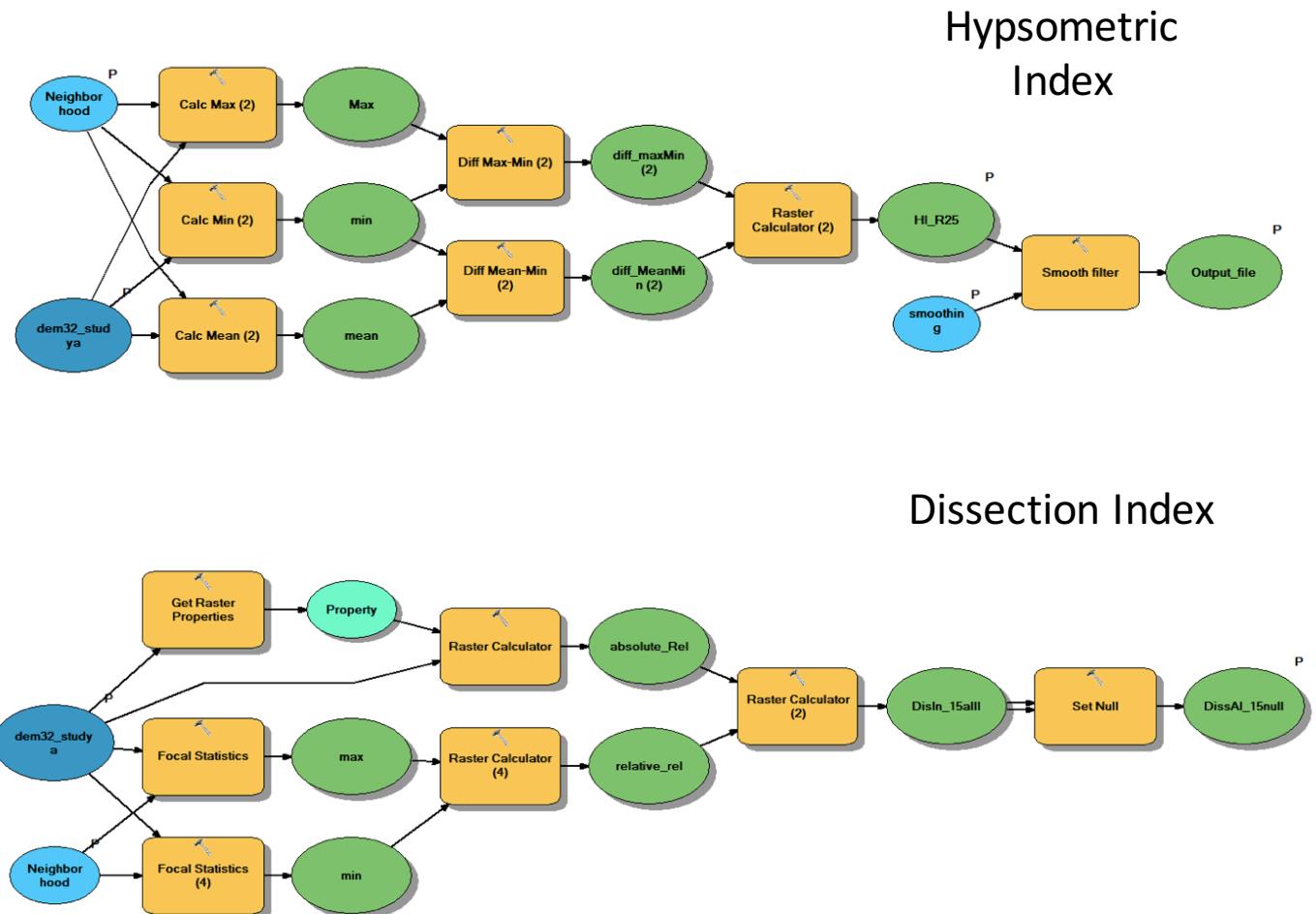
80/20% split

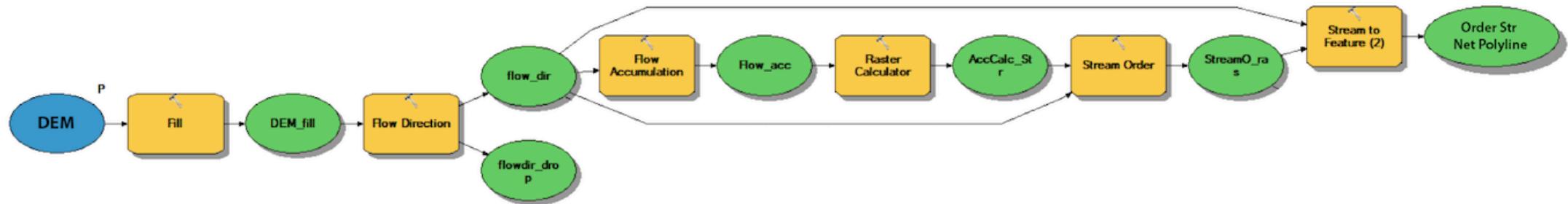
Training: 24 points

Validation: 7 points

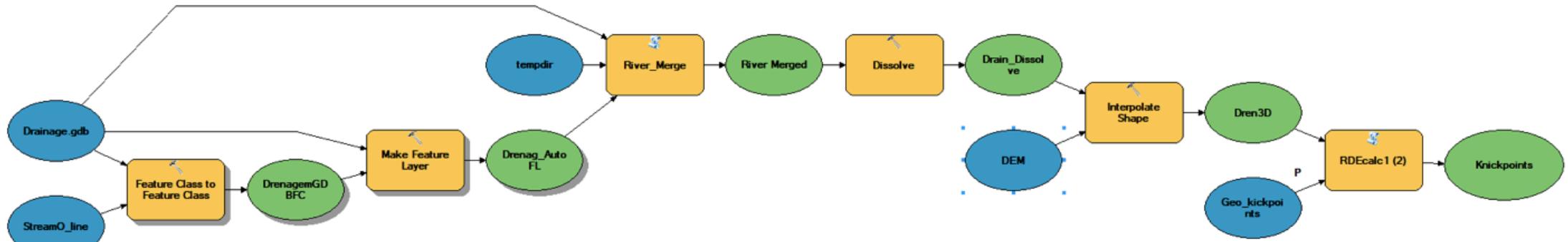
Data Creation: toolboxes

- Model builder & ArcPy
- Seven developed parameters
 - Stream Power Index
 - Topographic Wetness Index
 - Hypsometric Index
 - Dissection Index
 - Topographic Ruggedness Index
 - Vector Ruggedness Index
 - Knickpoints from river profiles



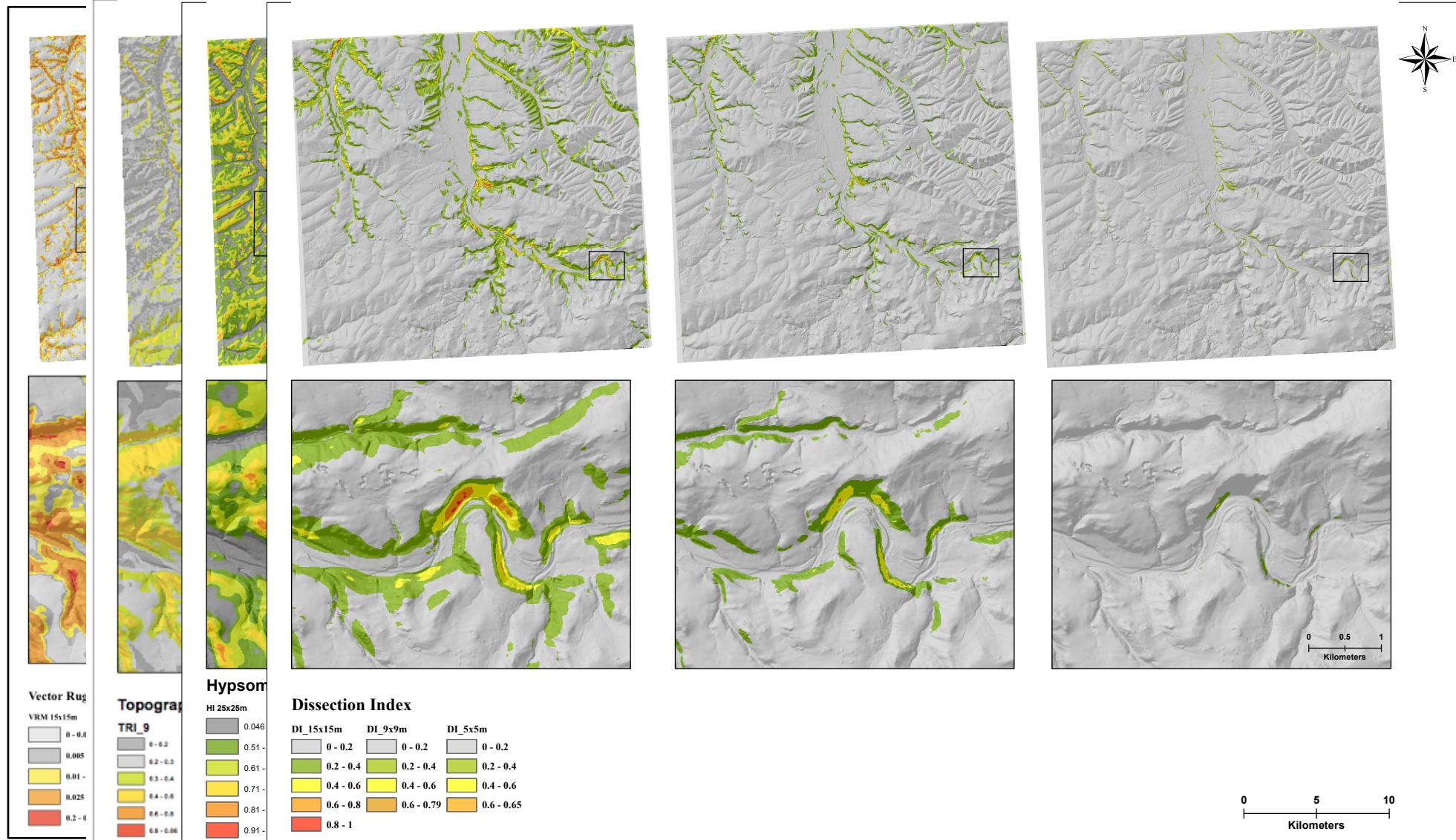


Drainage Extraction



Knickpoint Extraction

3. Methodology



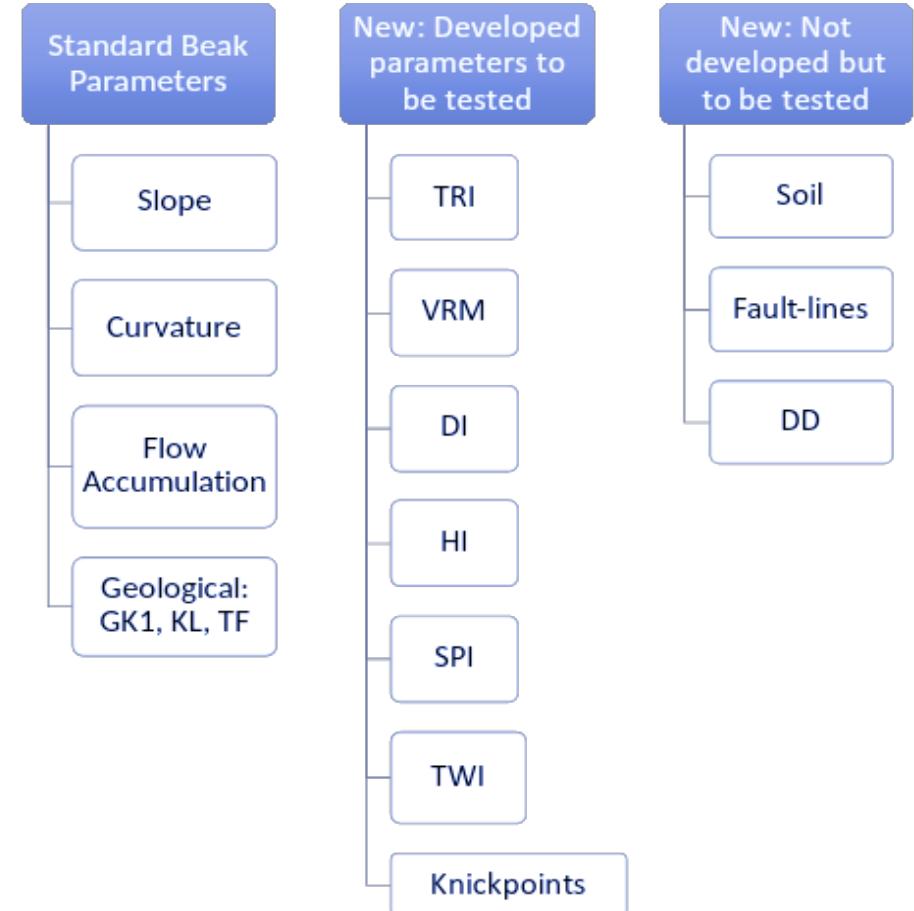
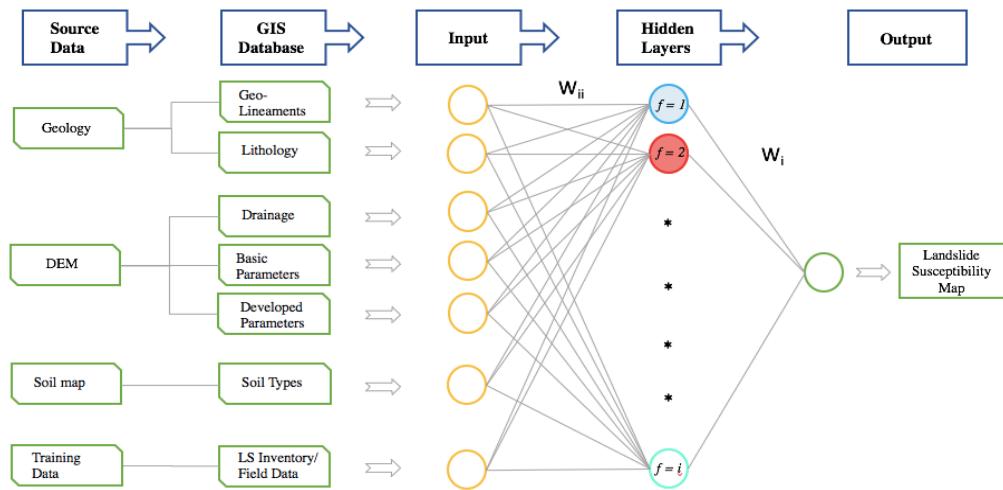
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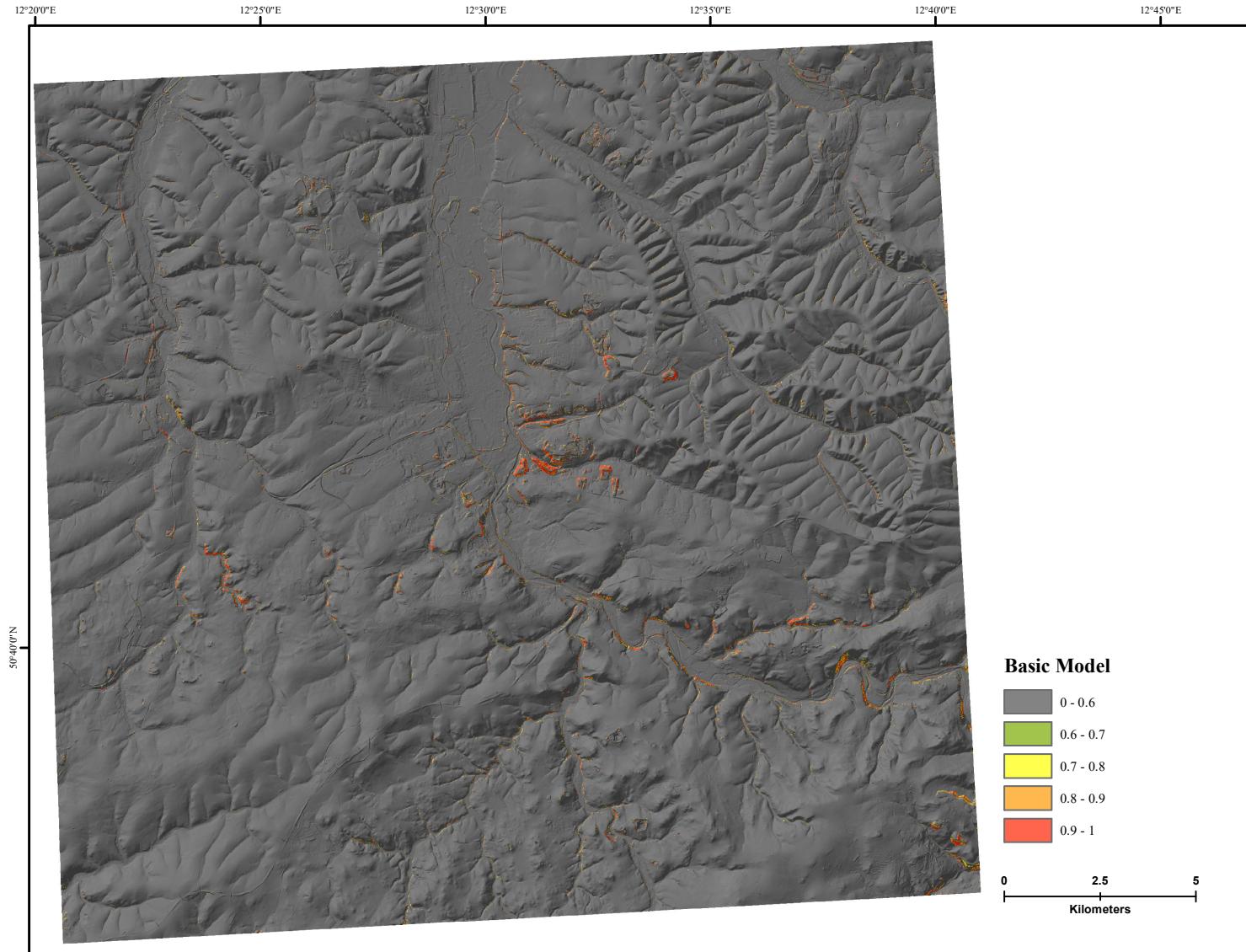
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trialed

3. Methodology

ANN modelling & setup in advango

- Previous model by beak using basic set of traditional parameters
- Layers needed to be binarized or scaled from 0-1
- ANN is a multi-layered perceptron utilizing a back propagation algorithm. Architecture is composed of 3 layers.

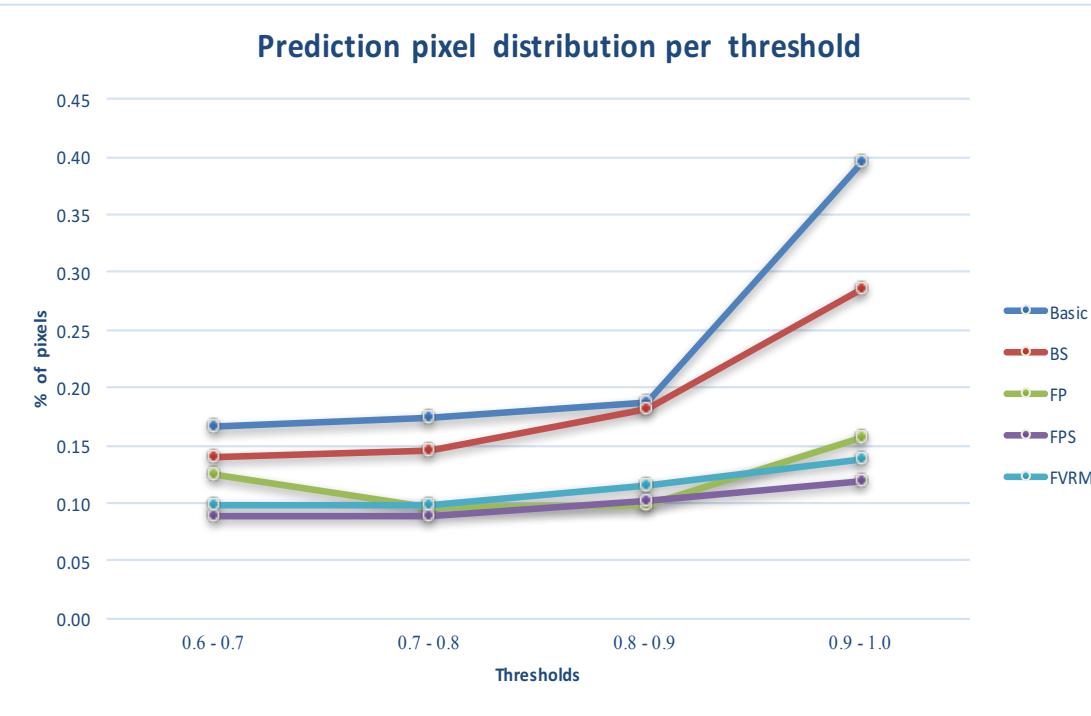




Model Results

- Results from 0-1
- 0.6-1 susceptible
- Each result is a raster average

Model Code	Description
Basic	High resolution 10m model using basic set of parameter inputs that were previously run by Beak Consultants GmbH at a lower resolution of 20m .
BS	The basic including soil data.
FP	Basic model plus tested parameters
FPS	Basic model plus tested parameters and soil
FVRM	Basic model plus optimised/selected parameters



Rank	Parameter
1	Curvature - Profile Neg
2	Curvature - Profile Pos
3	Curvature - Plan Neg
4	Curvature - Plan Pos
5	Slope
6	Flow Acc
7	TF
8	KL
9	GK1

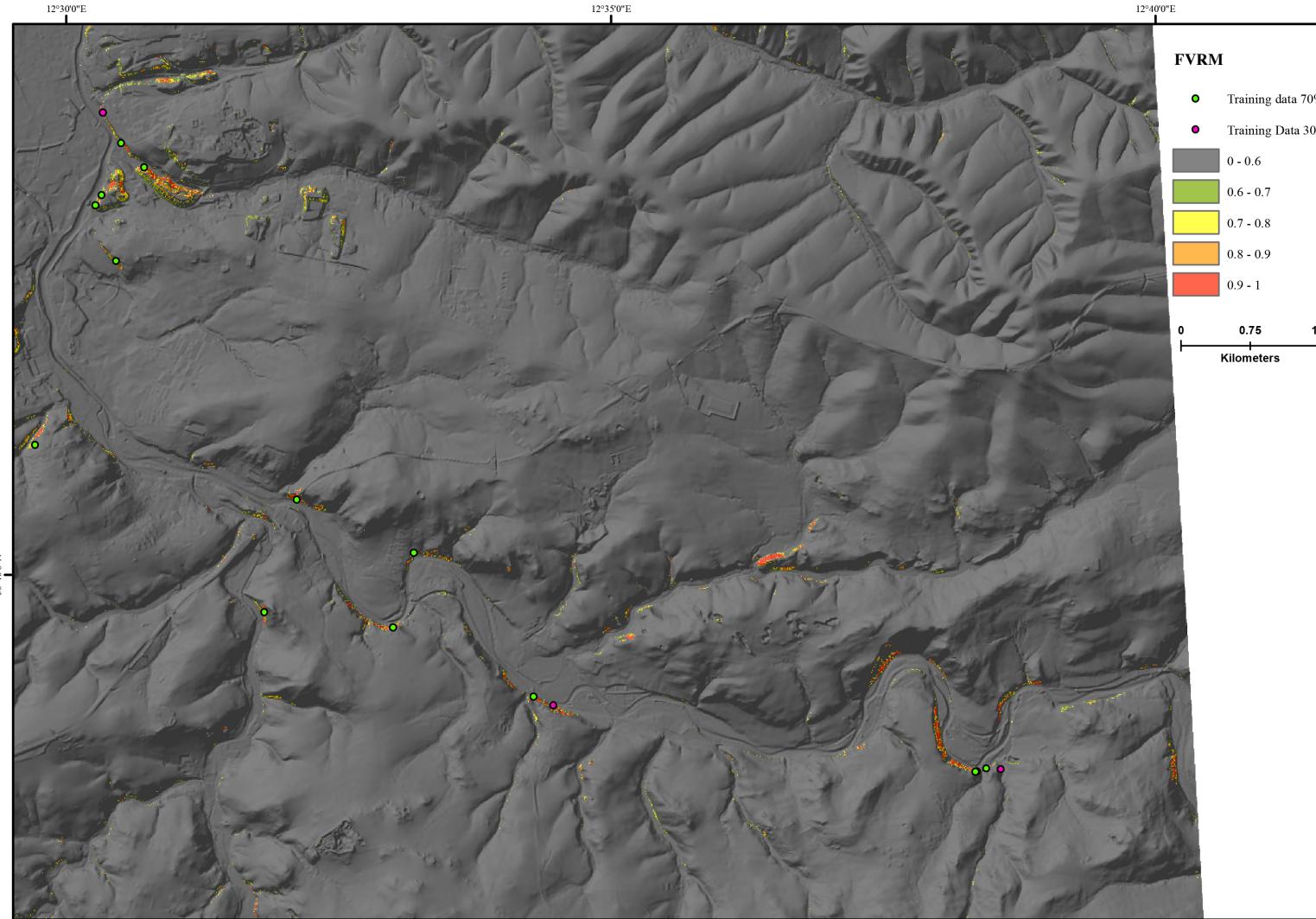
Basic Model

Rank	Parameter
1	Curvature - Profile Pos
2	Curvature - Profile neg
3	Curvature - Plan Neg
4	Slope
5	Curvature - Plan Pos
6	VRM 9
7	Flow Acc
8	Soil 2
9	KL
10	Soil 12
11	Faults
12	TF
13	DI 9
14	HI 15
15	SPI

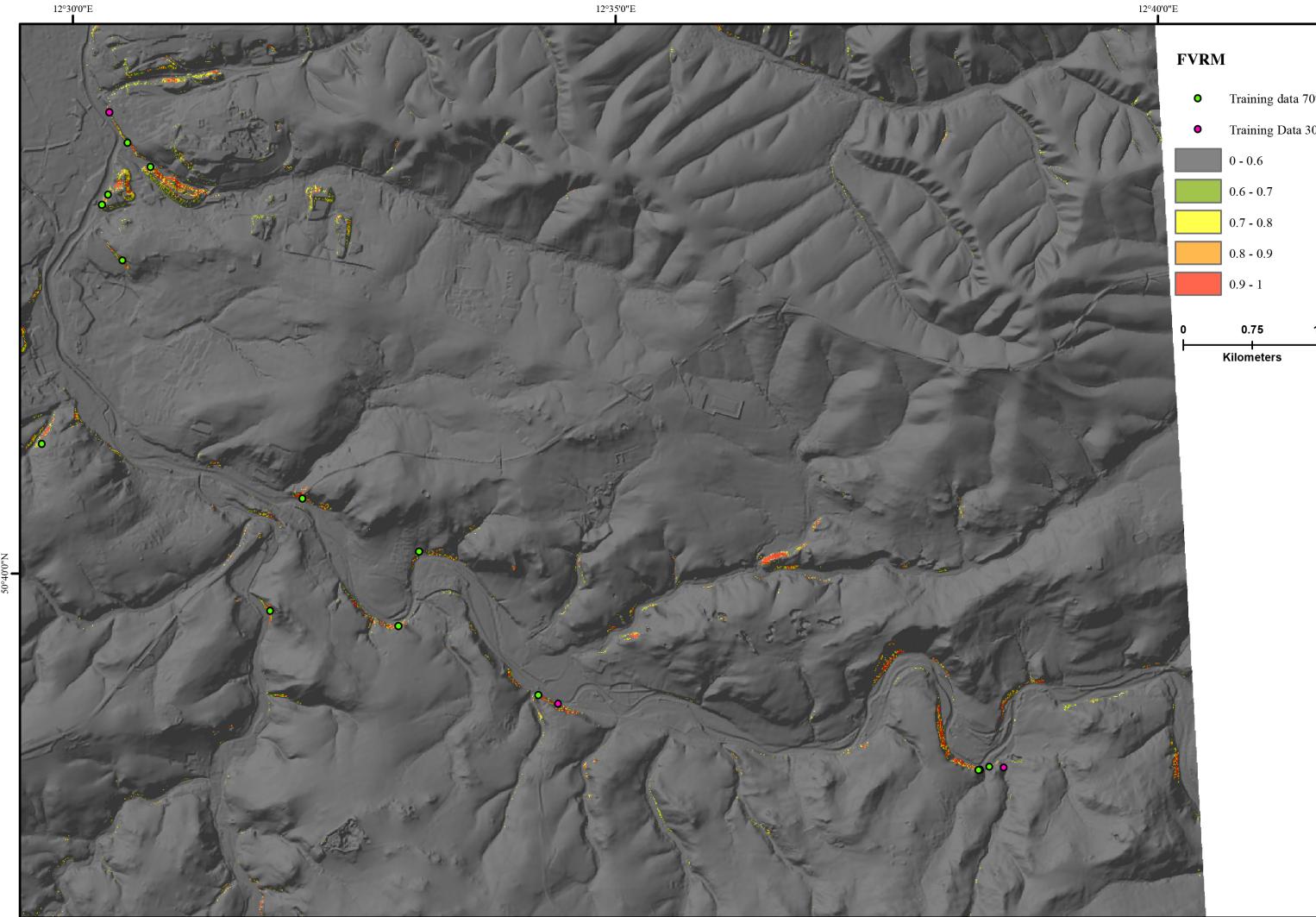
Parameter Model

- Prediction result pixel distribution is more stable for new parameter models
- Parameters ranked due to weight variation
- Multiple runs of the same model show variations in weights

4. Results and discussion



Visual Comparison:
Progression of model results



Visual Comparison:
Basic to final
parameter model



Visual comparison:
Difference map between final parameter model and basic model

Validation – Training Model

Model Code	Input #	Avg Error	Training pixel classification 0.9-1
Basic	6	0.00804566	86%
BS	13	0.00637834	91%
FP	19	0.00459187	93%
FPS	21	0.00359103	96%
FVRM	15	0.00337845	97%

Fig. model validation figures

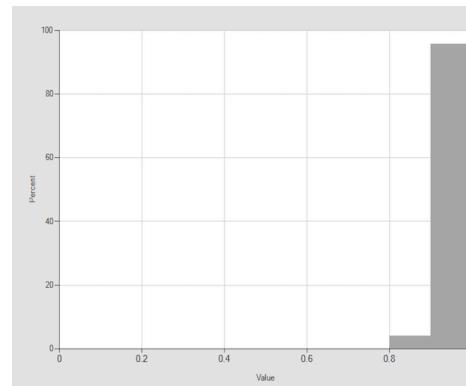
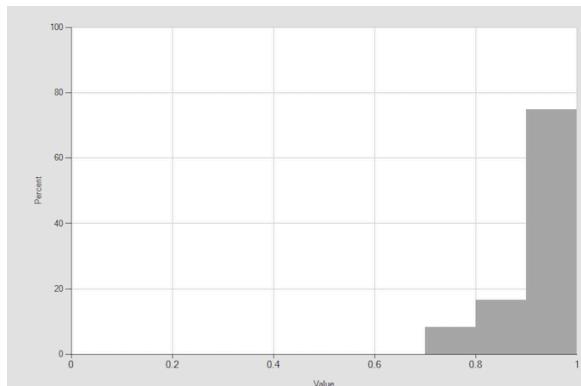


Fig. training pixel classification

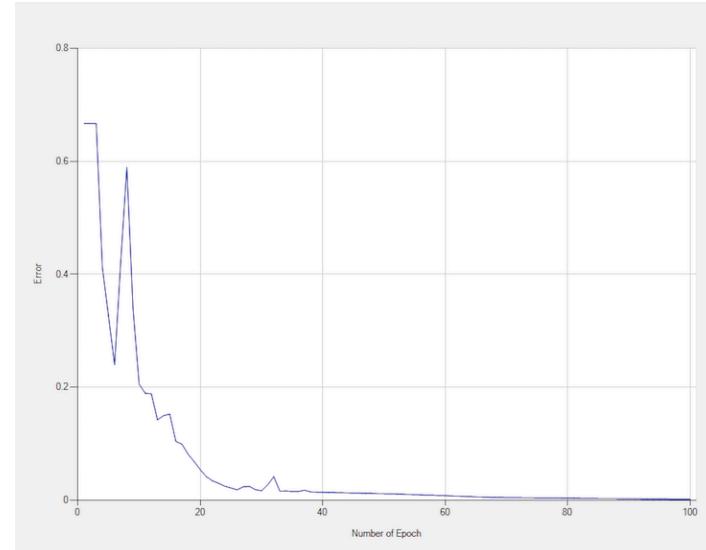


Fig. RMSE error plot over training period

- Model average error decrease from 0.008 to 0.0035%
- Training pixel classification increased from 86% to 97%

Validation – Applied model

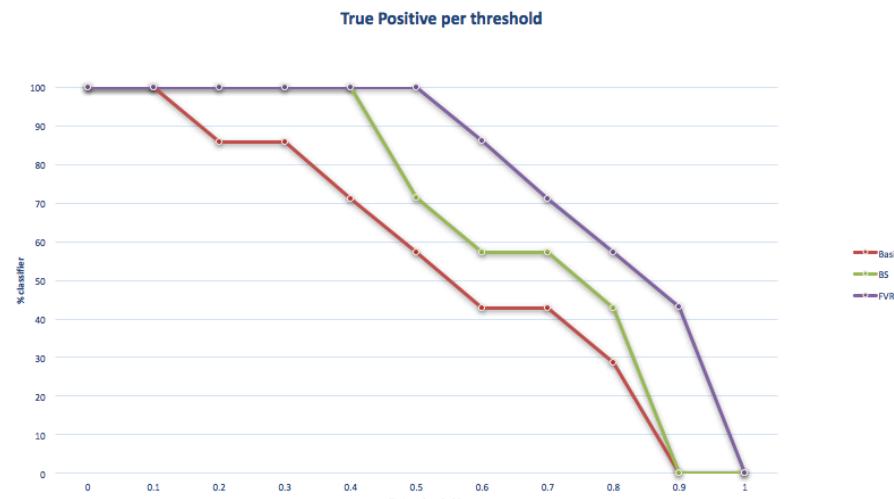


Fig. Validation point true positive classification per threshold

- True positive plot shows improvement in true positive classification from basic to final model
- ROC plot doesn't differentiate well due to the high false positive rate

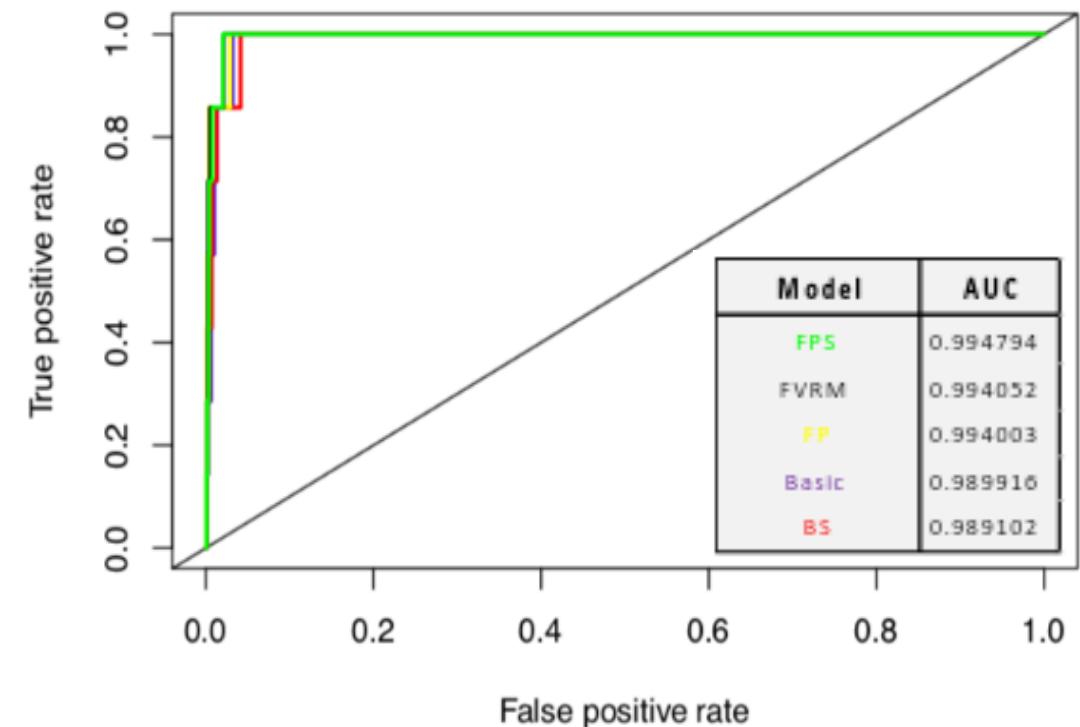


Fig. ROC and AUC results

$$TPR = TP / (TP + FN)$$

$$FPR = FP / (FP + TN)$$

Conclusion: Parameters

- Various parameters and methodologies were **reviewed** and evaluated and **seven parameters** chosen and **developed successfully** for evaluation.
- Results of this study show an **improvement** in the landslide susceptibility prediction when **new parameters** are included in the modelling process.
 - A **limitation** is that determining the exact effects of each parameter is not possible due to the black box nature of the ANN.
- The **Vector Ruggedness Measure** parameter proved the most influential overall and ranked the highest among multiple model comparisons.

Conclusion: Susceptibility modelling

- As discussed in the literature, **ANN** is an **effective method** of modelling complex non-linear data using **limited training data**, this has been confirmed during the research.
 - Various **combinations of training points** results don't cause major variations
- Models were **averaged** over multiple re-runs of the same model to even the resultant raster.
- Determining parameter influence for model comparison is not possible through weights alone, **rankings** of importance
- Running **low pass filter** over solidifies the result and reduces scattered prediction pixels

Conclusions: Validation

- **Validation** of the ANN **training phase** showed a decrease in error and an increase in training pixel classification.
- **Validation** of the applied model with the **validation points** further confirms the visual improvements seen through progressive prediction models.

Further work and recommendation:

- **Investigate VRM further to determine it's effects in other scenarios**
 - **Different resolutions, scales & test areas**
- **Run further model scenarios** including the rest of the parameters.
- Investigate further the **knickpoints** and better ways of modelling the distribution
- **Global versus local minima** issue improvements can increase model consistency and speed up the process.

Image Sources:

Slide 5:

- <https://www.schiebener.net/wordpress/aktuell-erdrutsch-an-der-l740-sudlich-von-silbach/>
- https://www.google.de/imgres?imgurl=https://bilder.t-online.de/b/77/92/42/70/id_77924270/610/tid_da/mitarbeiter-der-deutschen-bahn-zwischen-den-geroellmassen-eines-erdrutsches-auf-den-gleisen-.jpg&imgrefurl=https://www.t-online.de/nachrichten/panorama/id_77924266/wetter-bahnstrecke-dresden-prag-wieder-frei.html&h=343&w=610&tbnid=QKdp0JAQL5mX_M&tbnh=168&tbnw=300&usg=AI4_-kR3mRG5154NTTu-rb9IvdHPCUmvsg&vet=1&docid=r6g9RD__HPKw4M

Slide 7

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Thank you for your attention!

Any Questions?