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Erosion

Prediction of Rainfall-Generated Soil Erosion Processes with Artificial Neural Networks and GIS

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FRAGILE EARTH
Session T8E
Munich, 05.09.2011

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Agenda

- **Theoretical Background: Artificial Intelligence / Artificial Neural Networks**
- **Short Presentation of Developed Software *advangeo®* and of the Developed Extension *advangeo® Erosion***
- **Description of Work Methodology:**
  - Case Study: Risk Analysis Glashütte Flood Control Reservoir Catchment Area
    - *Extensive Soil Erosion*
    - *Erosion Gullies*
    - *Soil Sliding / Creeping*
- **Further Case Studies**
- **Summary**
- **Information Sources:** Booth / Webpage

Motivation

Where are the deposits located ?

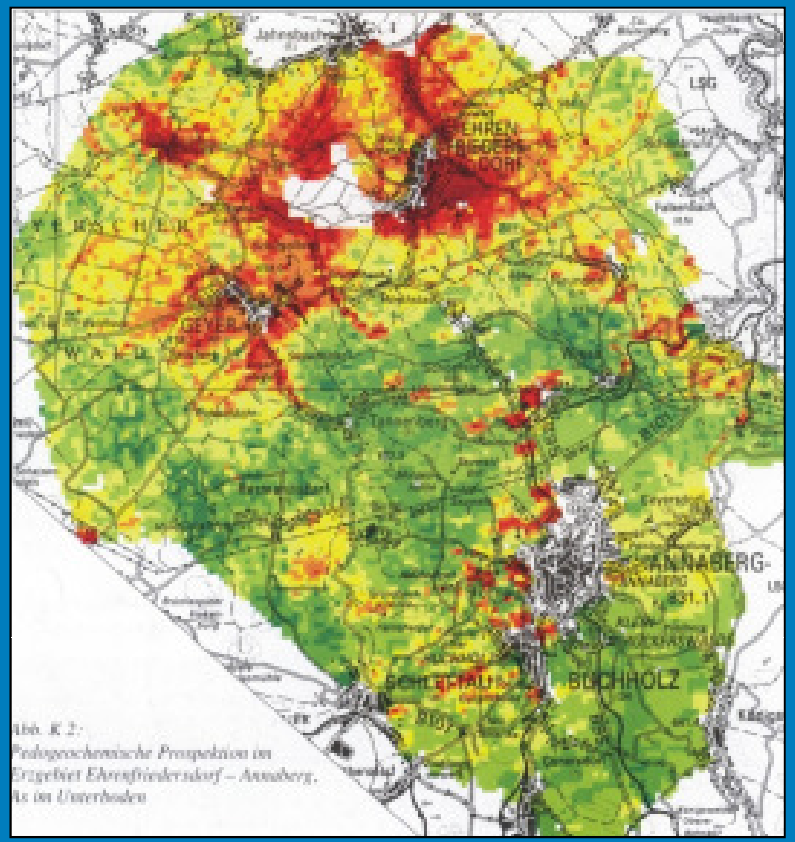
Where do forest pests spread ?

Where does coal burn ?

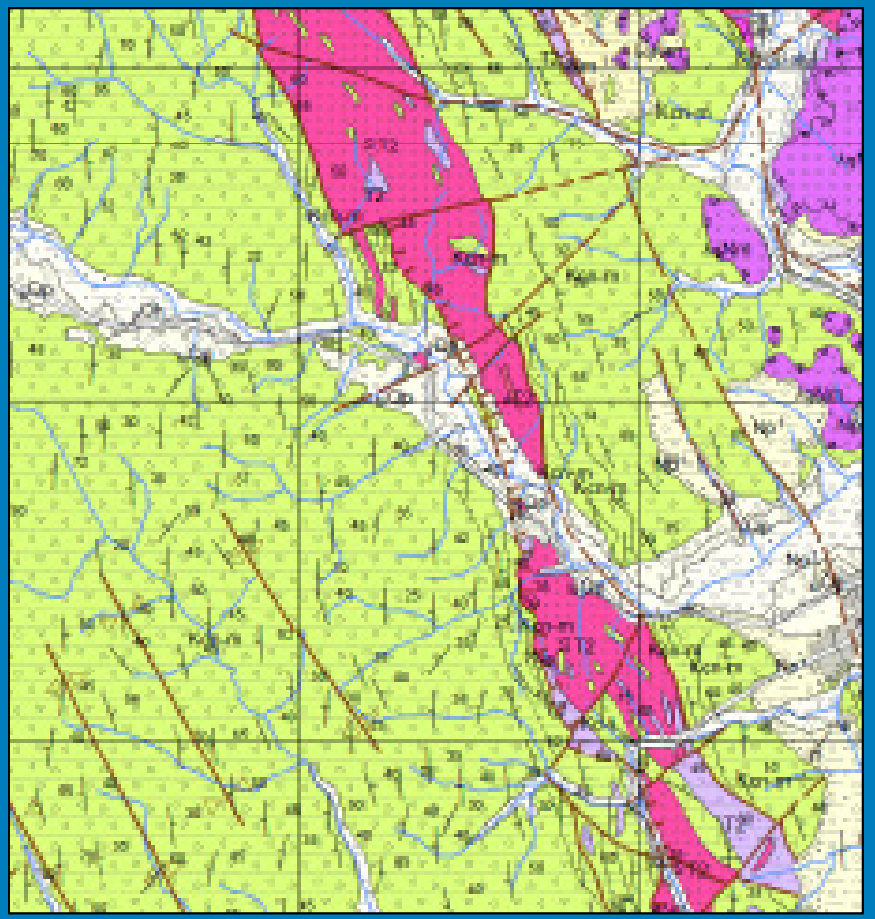
Where are karst caves located ?

Motivation

Where is soil contaminated ?



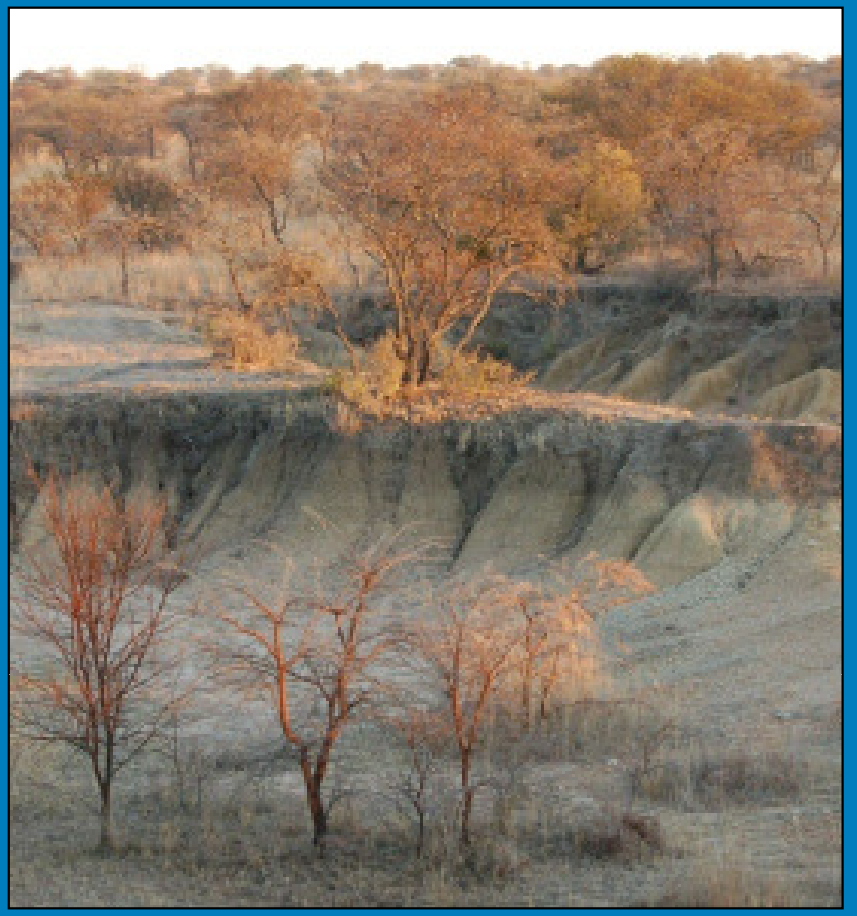
Where is a geological / pedological boundary?



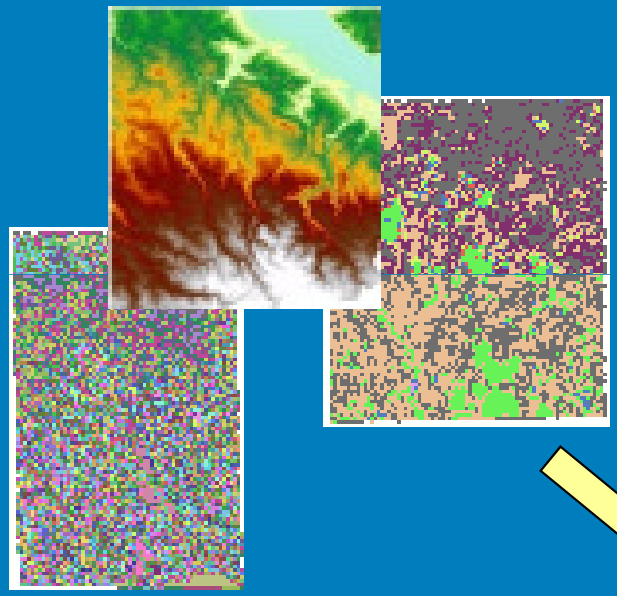
Motivation

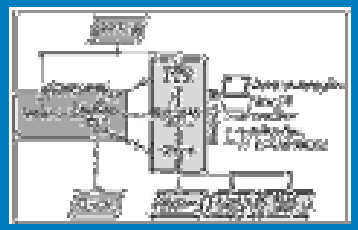
Where do hillside slides occur?

Where do erosion gullies form?

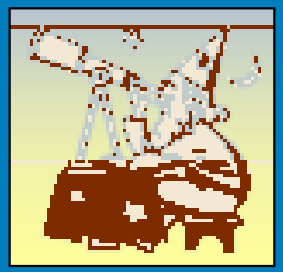


Predictive Mapping: Traditional Approach

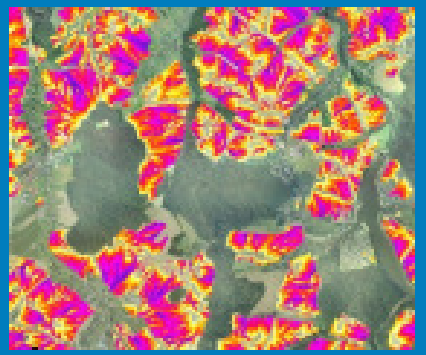




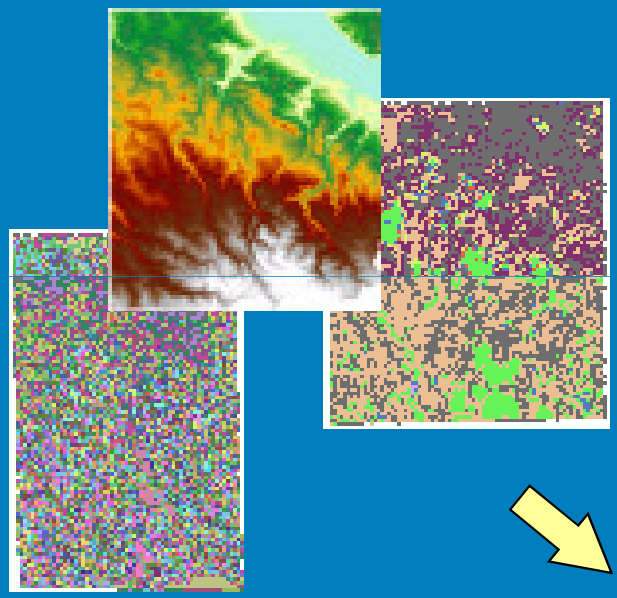
Traditional prediction methods are based mainly on the expert´s knowledge / experience supported by modern information technology

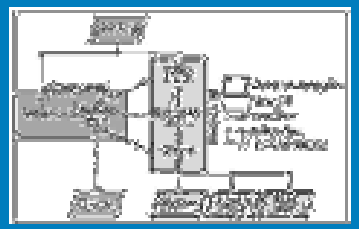


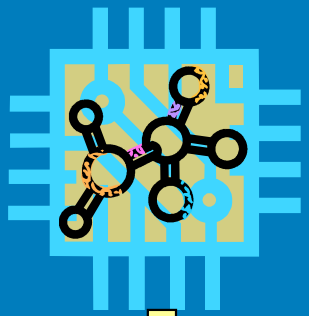
Data Analysis and Interpretation

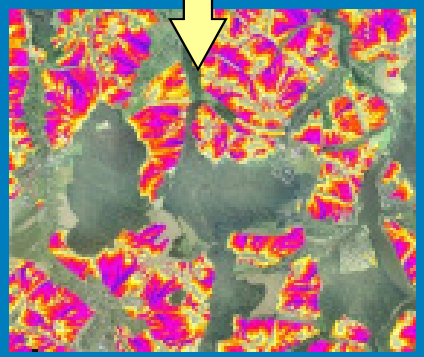


Predictive Mapping: Modern Approach Using Artificial Intelligence







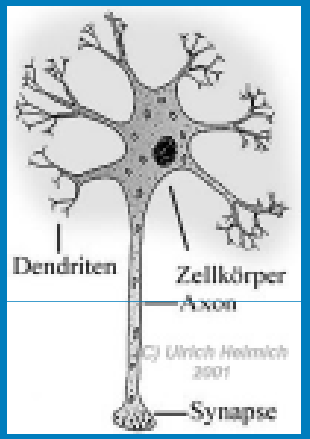


The artificial neuronal network "replaces" the experts empirical data analysis

Pre-Processing

Validation

Definition: Artificial Neural Networks

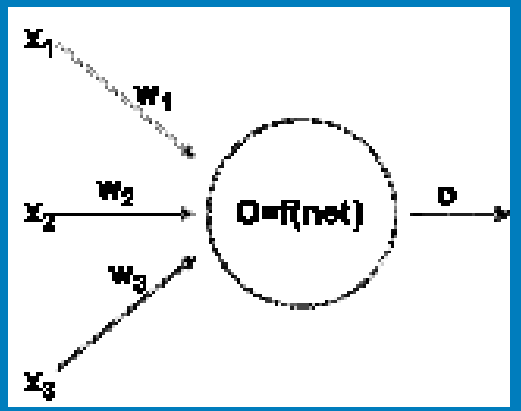


Modell: Neuron Cell

- Functionality as a biological neural system
- Consists of artificial neuron cells
- Simulation of biological processes of neurons by use of suitable mathematical operations
- In most cases layer-like configuration of the neurons

The Neuron Cell as a Processor

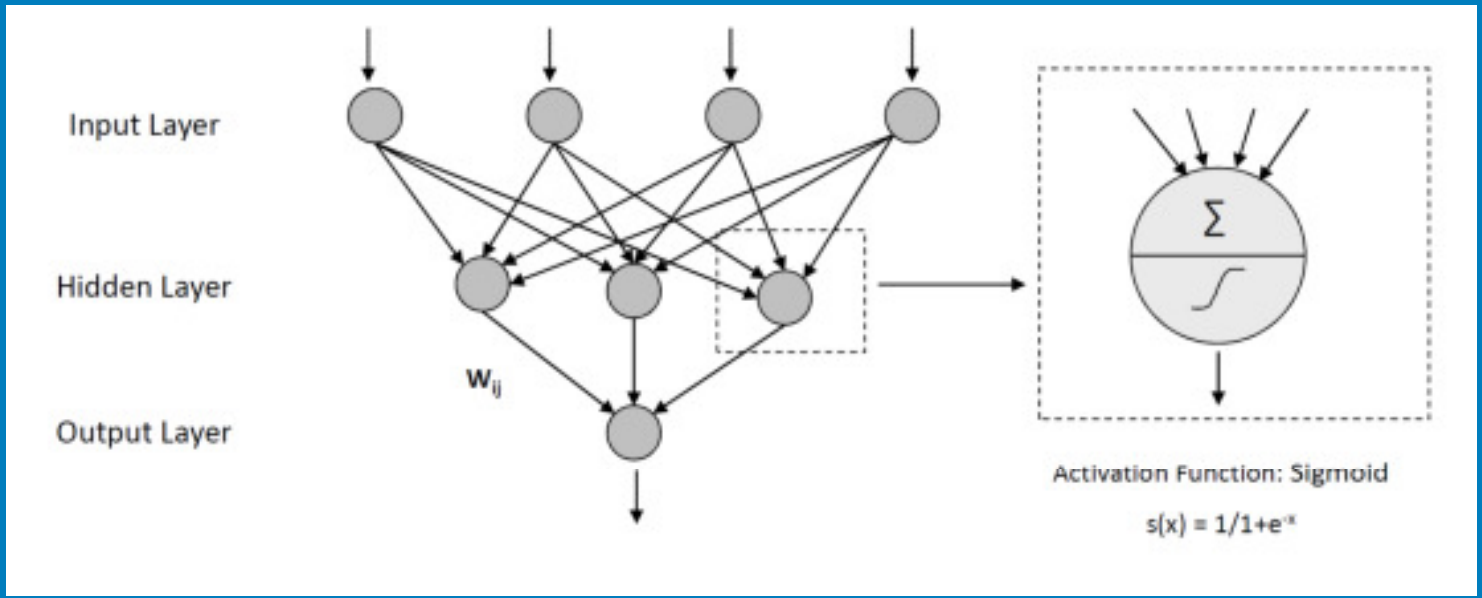
- **Connection between the neurons by weights w**
  - Enforce or reduce the level of the input information
  - Are directed, can be trained
- **Input signals**
  - Re-computed to a single input information: the propagation function
- **Output signals**
  - Activation function computes the output status of a neuron (often used: Sigmoid function)



Principle Setup of Artificial Neural Networks

Network Topology: MLP (Multi Layer Perceptron)

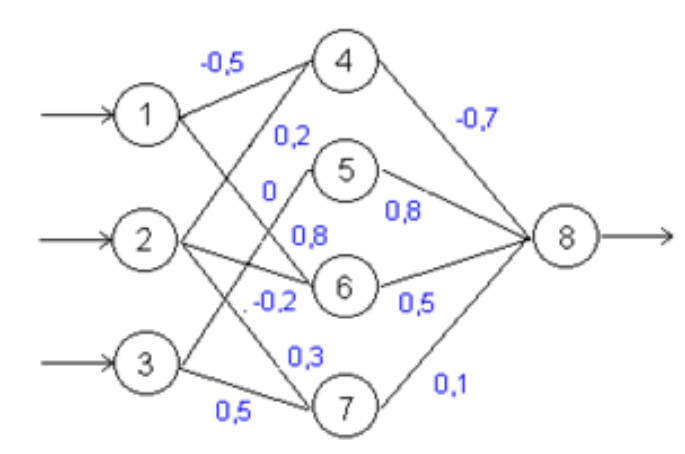
- Set-up of neurons in layers
- Direction and degree of connections
- Amount of hidden layers and neurons

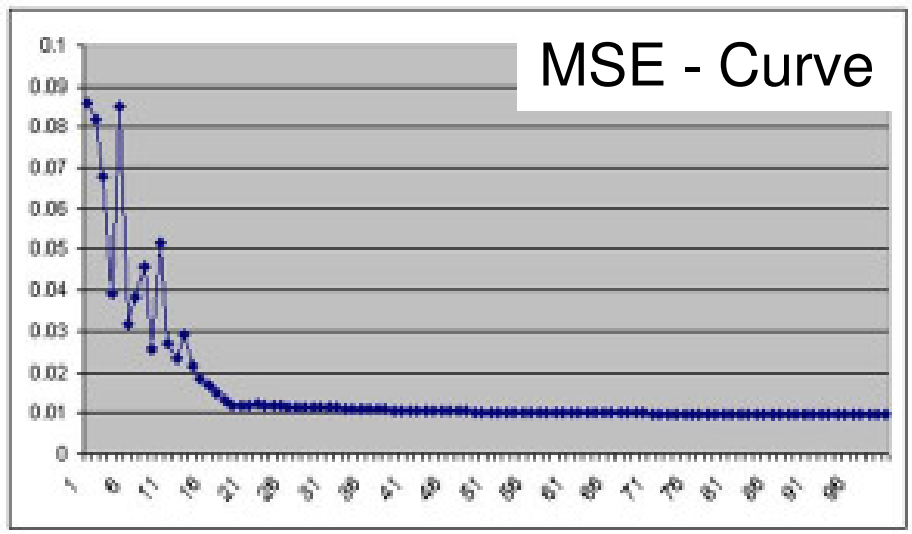


Training of Artificial Neural Networks

Learning Algorithm: Back-Propagation

- Repeated input of training data
- Modification of weights w
- Reduces error between expected and actual output of the network





Advantages / Disadvantages of Artificial Neural Networks

Advantages:

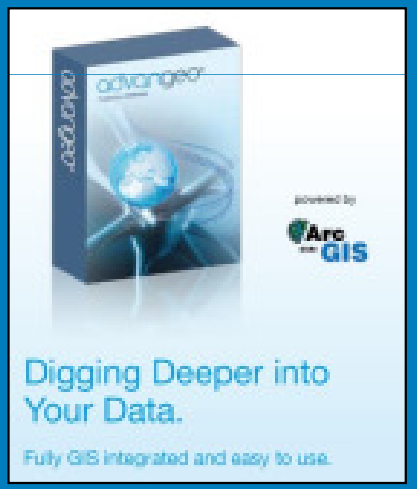
- ***learnable***: learning from examples
- ***generalization***: able to solve similar problems that have not been trained yet
- ***universal***: prediction, classification, pattern recognition
- able to analyze complex, ***non-linear*** relationships
- ***fault-tolerant*** against noisy data (e.g. face recognition)
- ***quick***

Additional characteristics:

- choice of ***topology*** and ***training algorithm***
- ***black box system***: evaluation of weight of parameters

Software: advangeo

- **Easy Access** to Methods of Artificial Intelligence for Spatial Prediction
- **Documentation** of Working Steps
- Capture and Management of **Metadata** for Geodata
- **Tools** for Data Pre-Processing, Post-Processing and Cartographic Presentation
- **Integration** into Standard ESRI ArcGIS-Software



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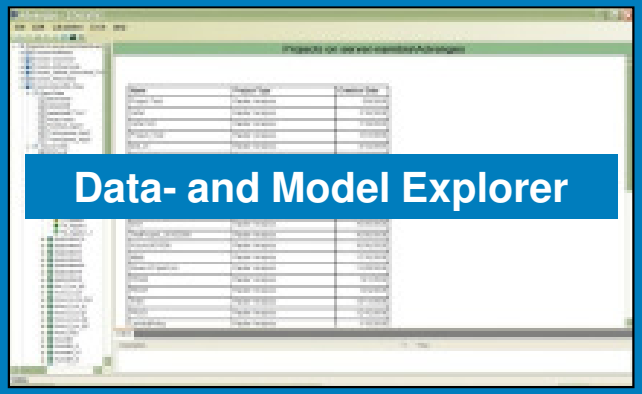
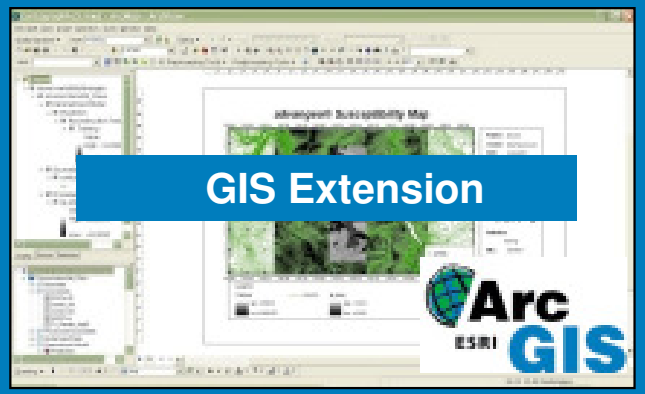
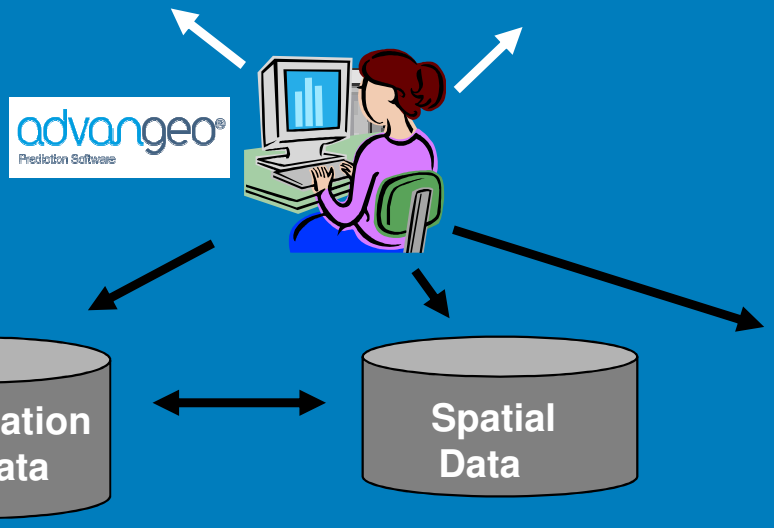
Software Components

+

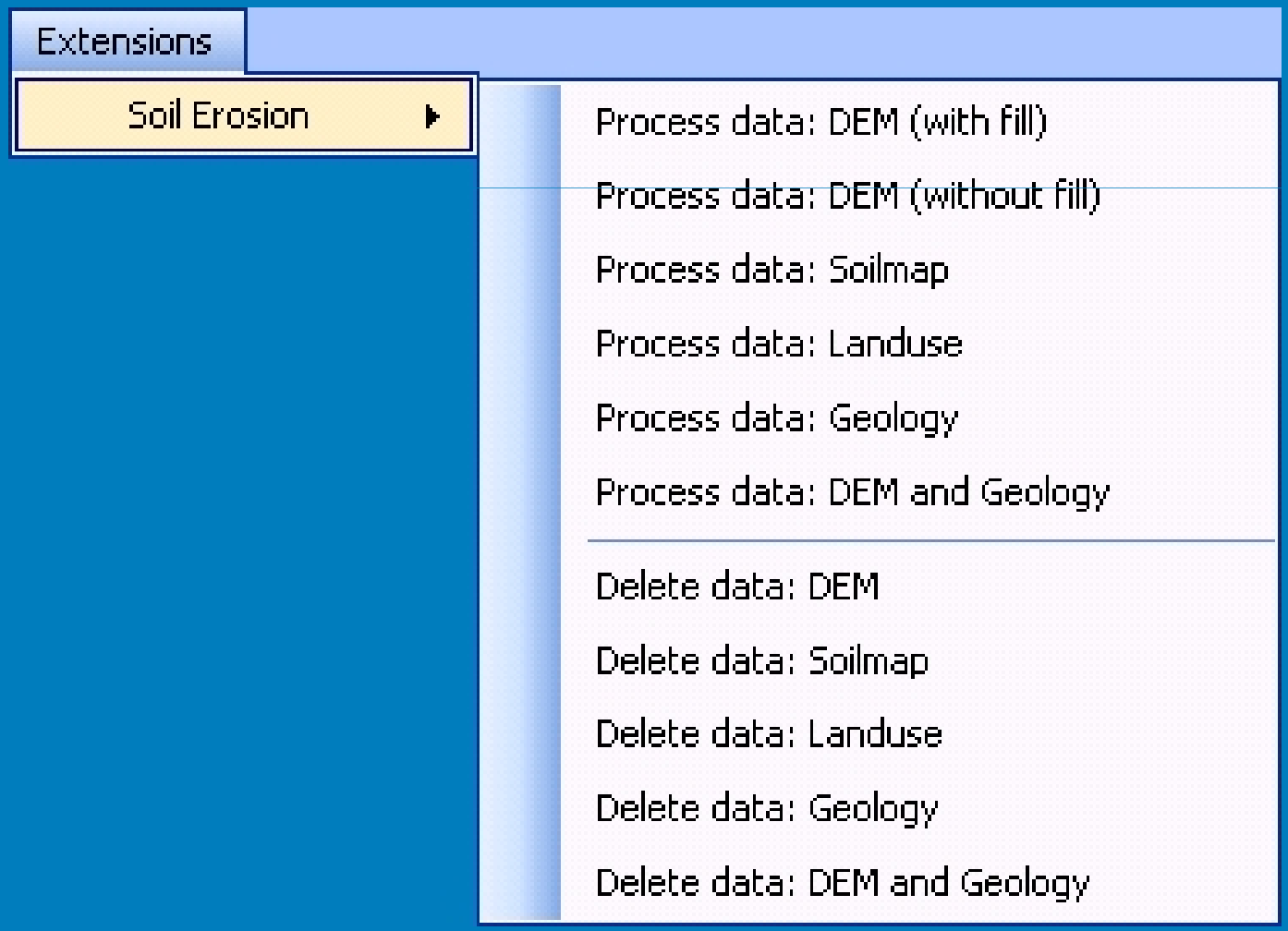




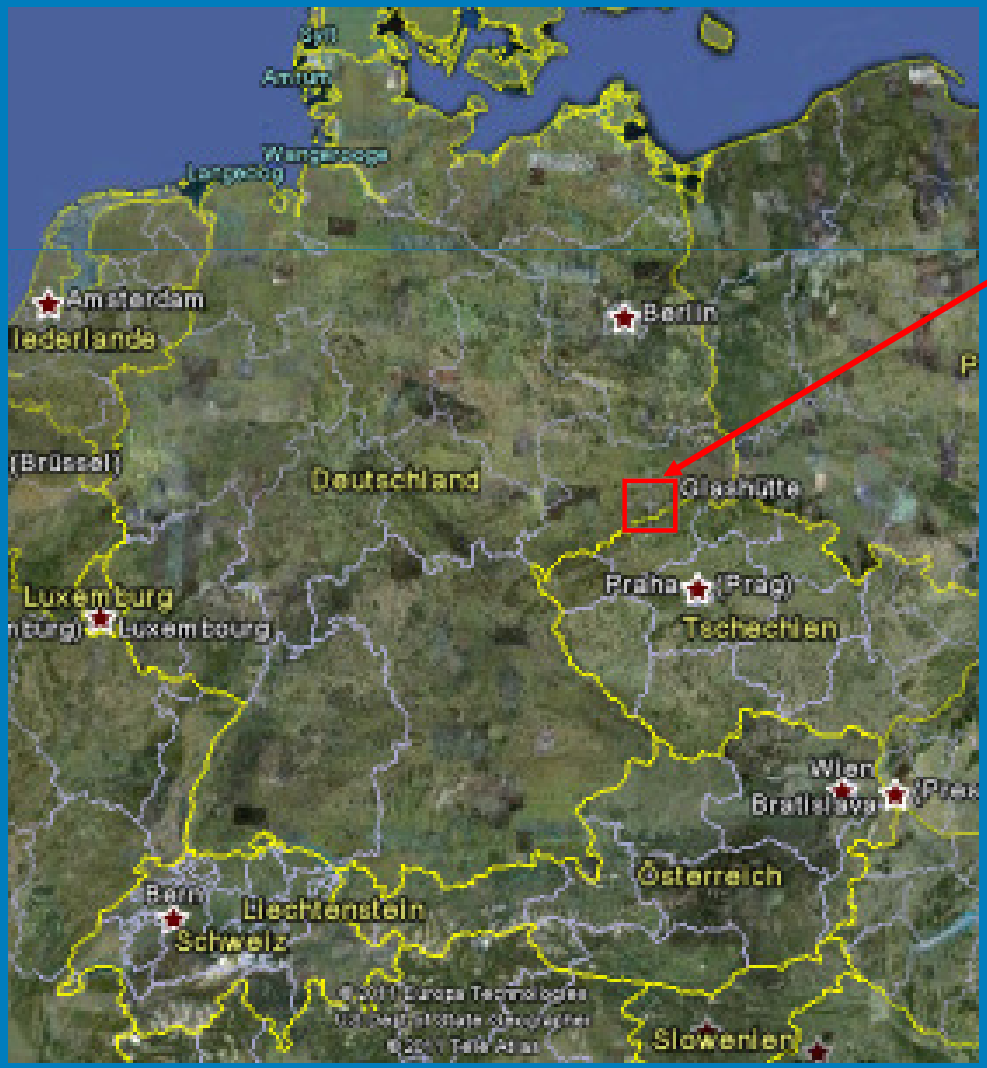


advangeo: Erosion Extension with Pre-Processing Tools

- **Soil Erosion Toolbar:** Overview



Case Study: Glashütte Flood Control Reservoir Catchment Area



Glashütte
Flood Control Reservoir
Catchment Area

LANDESTALSPERREN VERWALTUNG
des Freistaates Sachsen

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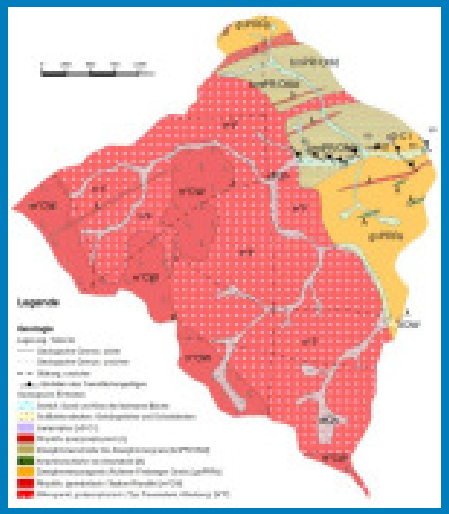
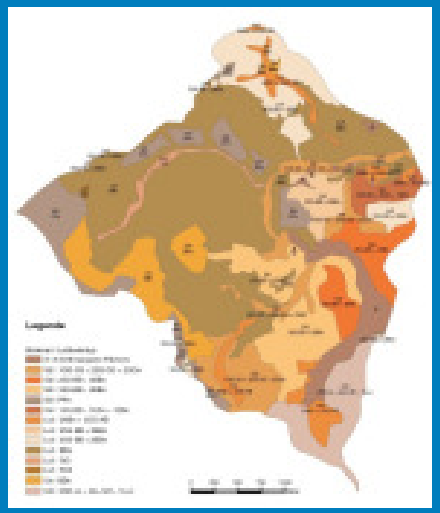
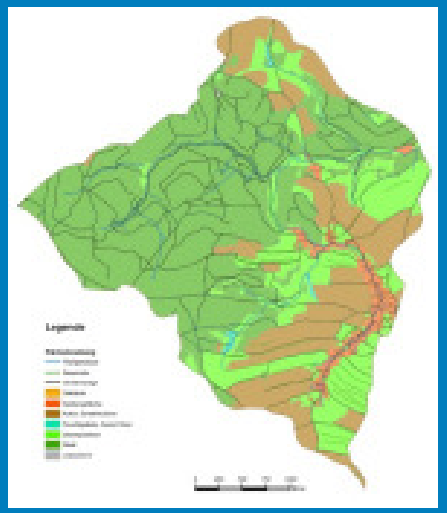
Case Study: Glashütte Flood Control Reservoir Catchment Area

Case Study: Glashütte Flood Control Reservoir Catchment Area

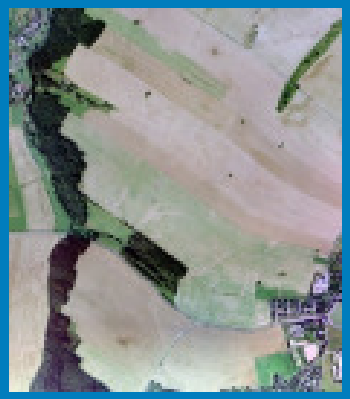
Available Knowledge and Input Data

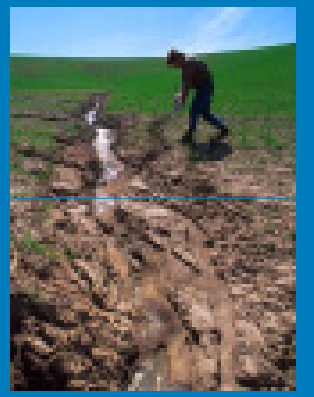




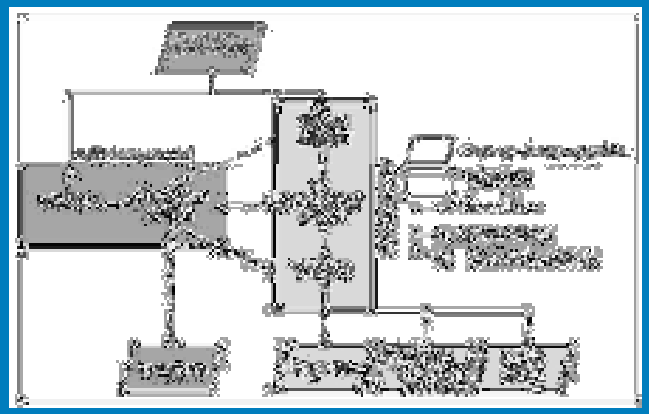


Data:
DEM,
Soil Map,
Landuse,
Geology



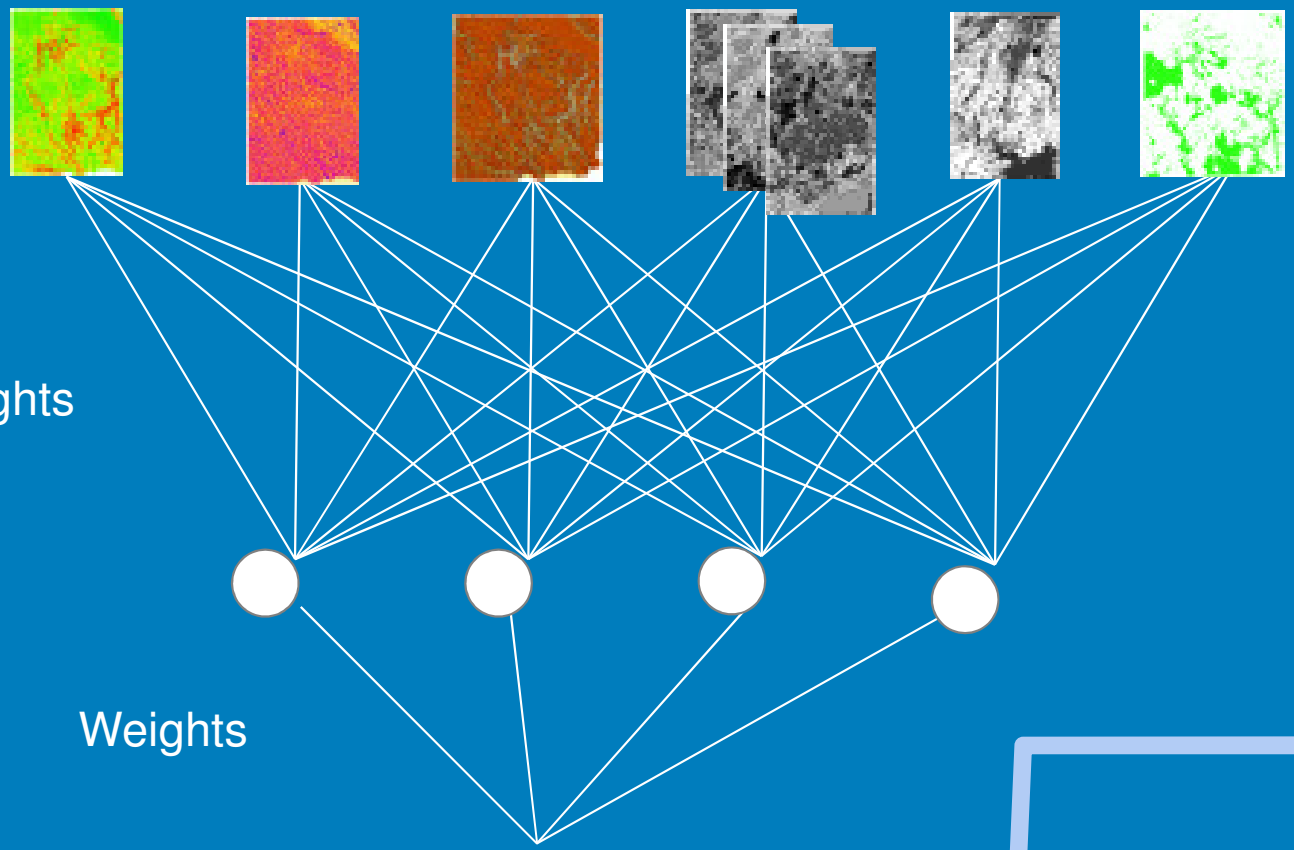


Knowledge: Aerial Images, Field Observations



Knowledge: Analytical Models

Case Study: Glashütte Flood Control Reservoir Catchment Area



Probability Modelling Workflow 1: Extensive Soil Erosion

Input Data

Elevation Model and its Derivates:
- *Slope*
- *Flow accumulation*

Soil:
- *Clay*
- *Silt*
- *Sand*
- *Fine skeleton*
- *Coarse skeleton*

Landuse
- *Grassland*
- *Open area without vegetation*
- *Cropland*
- *Urban / industrial areas*

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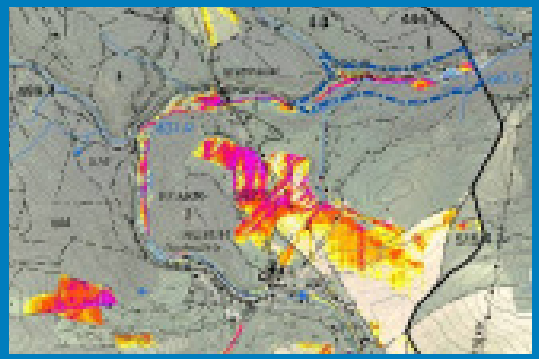
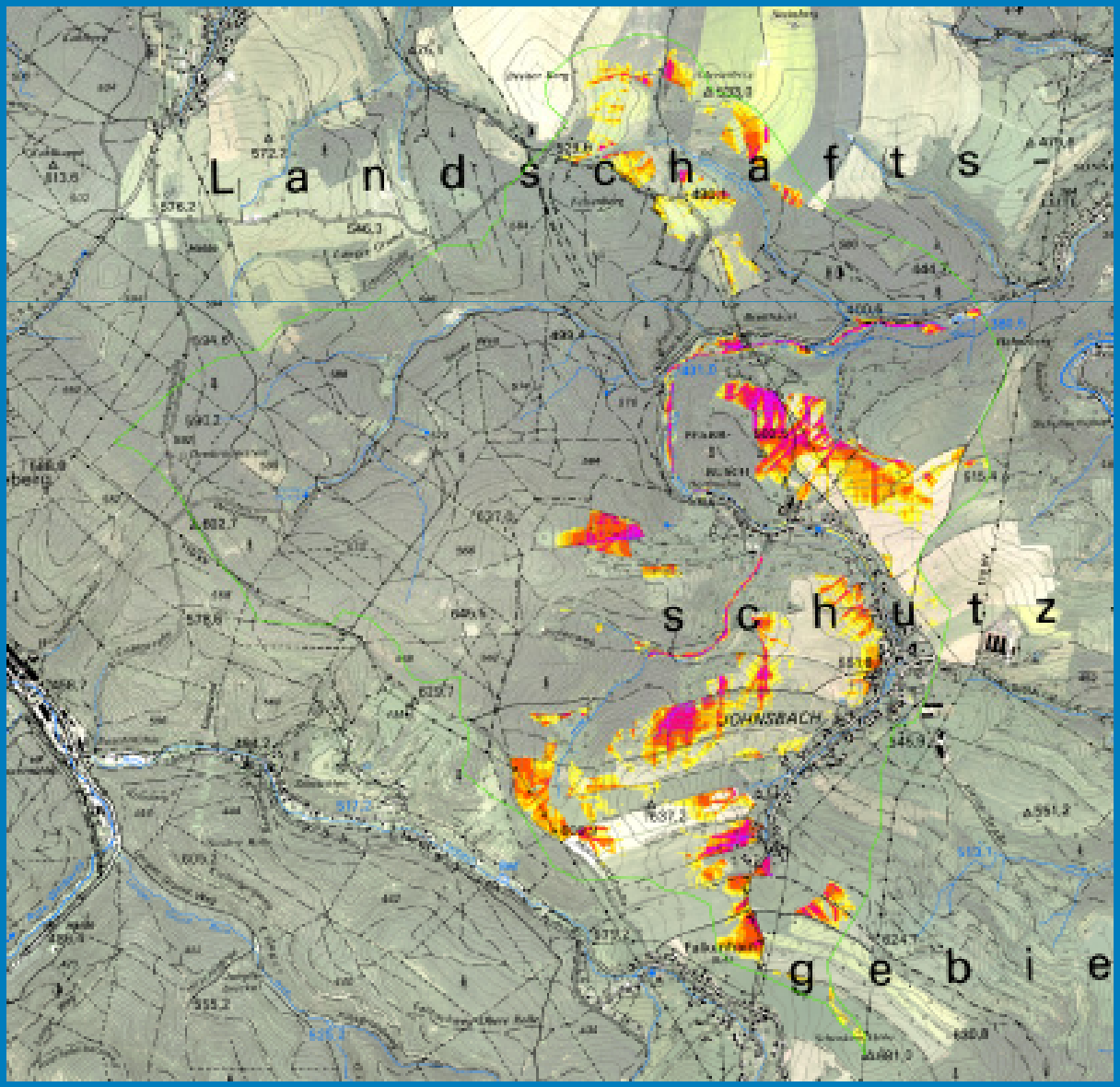


Training Data

Known Areas with Extensive Soil Erosion

Probability Modelling Results 1: Extensive Soil Erosion



Legende

Arbeitsgebiet

Einzugsgebiet HRB Glashütte

HRB Glashütte

Dammkronenwasserspiegel (geplant: 408,20m üNN)

Gefährdung durch flächenhaften Bodenabtrag

Eintrittswahrscheinlichkeit

- < 55 %
- 55 - 60 %
- 60 - 65 %
- 65 - 70 %
- 70 - 75 %
- 75 - 80 %
- 80 - 85 %
- 85 - 90 %
- 90 - 95 %
- 95 - 100 %

Probability Modelling Workflow 2: Erosion Gullies

Input Data

Elevation Model and its Derivates:

- *Slope*
- *Flow accumulation*

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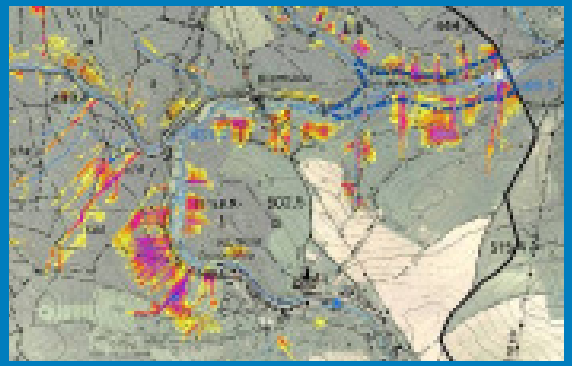
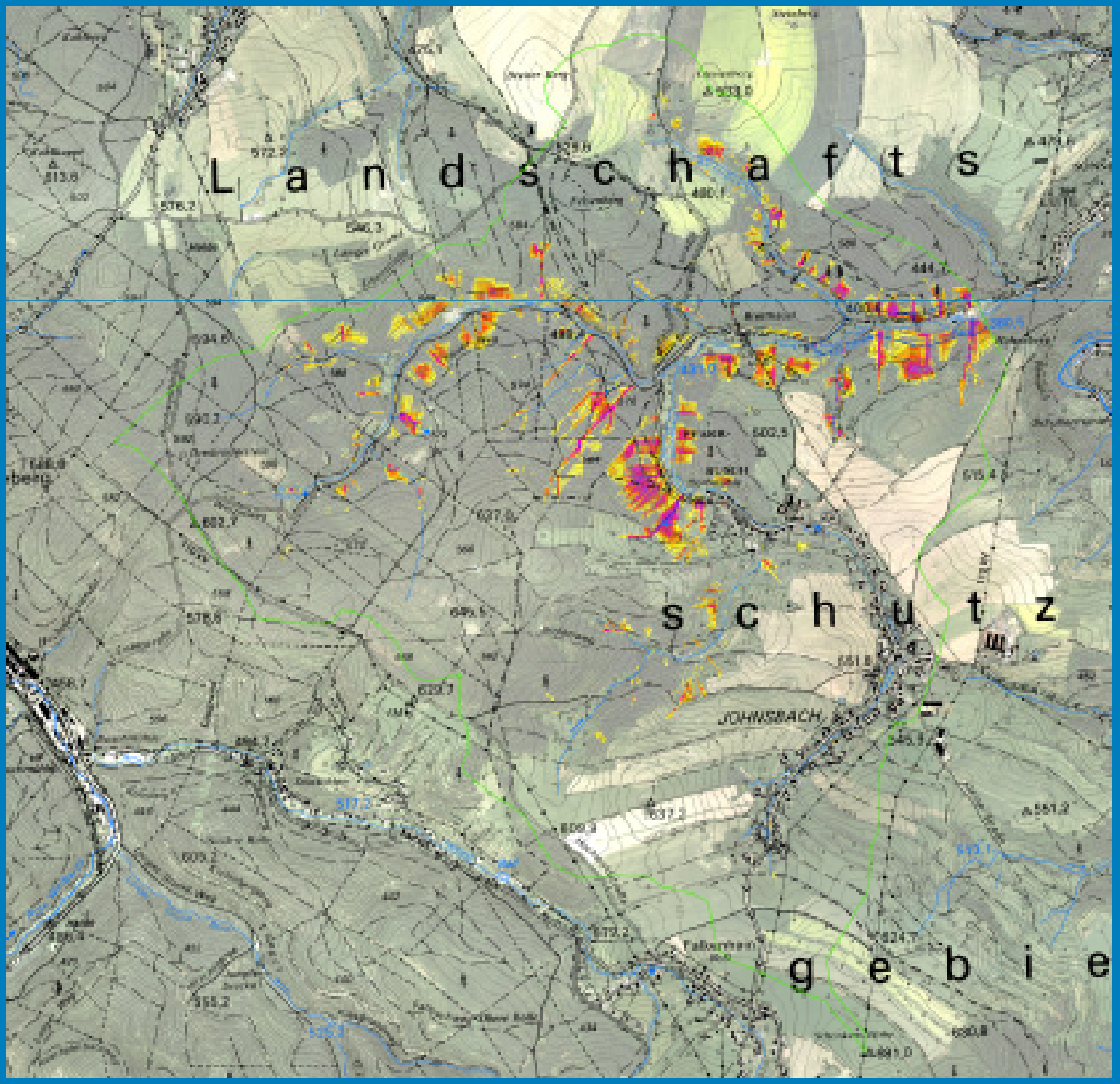


Training Data

Known Areas with Erosion Gullies

Probability Modelling Results 2: Erosion Gullies



Legende

Arbeitsgebiet

Einzugsgebiet HRB Glashütte

HRB Glashütte

Dammkronenwasserspiegel (geplant: 408,20m üNN)

Gefährdung durch Erosionsrinnen / -schluchten

Eintrittswahrscheinlichkeit

- < 55 %
- 55 - 60 %
- 60 - 65 %
- 65 - 70 %
- 70 - 75 %
- 75 - 80 %
- 80 - 85 %
- 85 - 90 %
- 90 - 95 %
- 95 - 100 %

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Probability Modelling Workflow 3: Soil Sliding / Creeping

Input Data

Elevation Model and its Derivates:
- *Slope*
- *Exposition N/S*
- *Exposition W/E*

Geology:
- *Dip angle*
- *Dip direction N/S*
- *Dip direction W/E*

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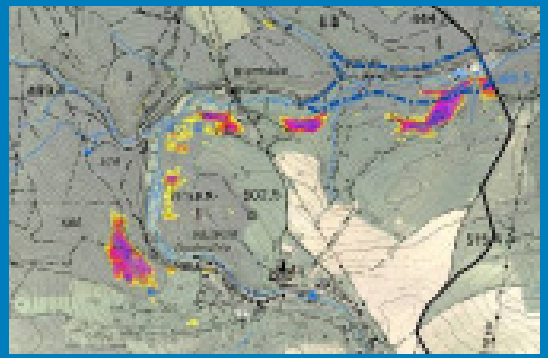
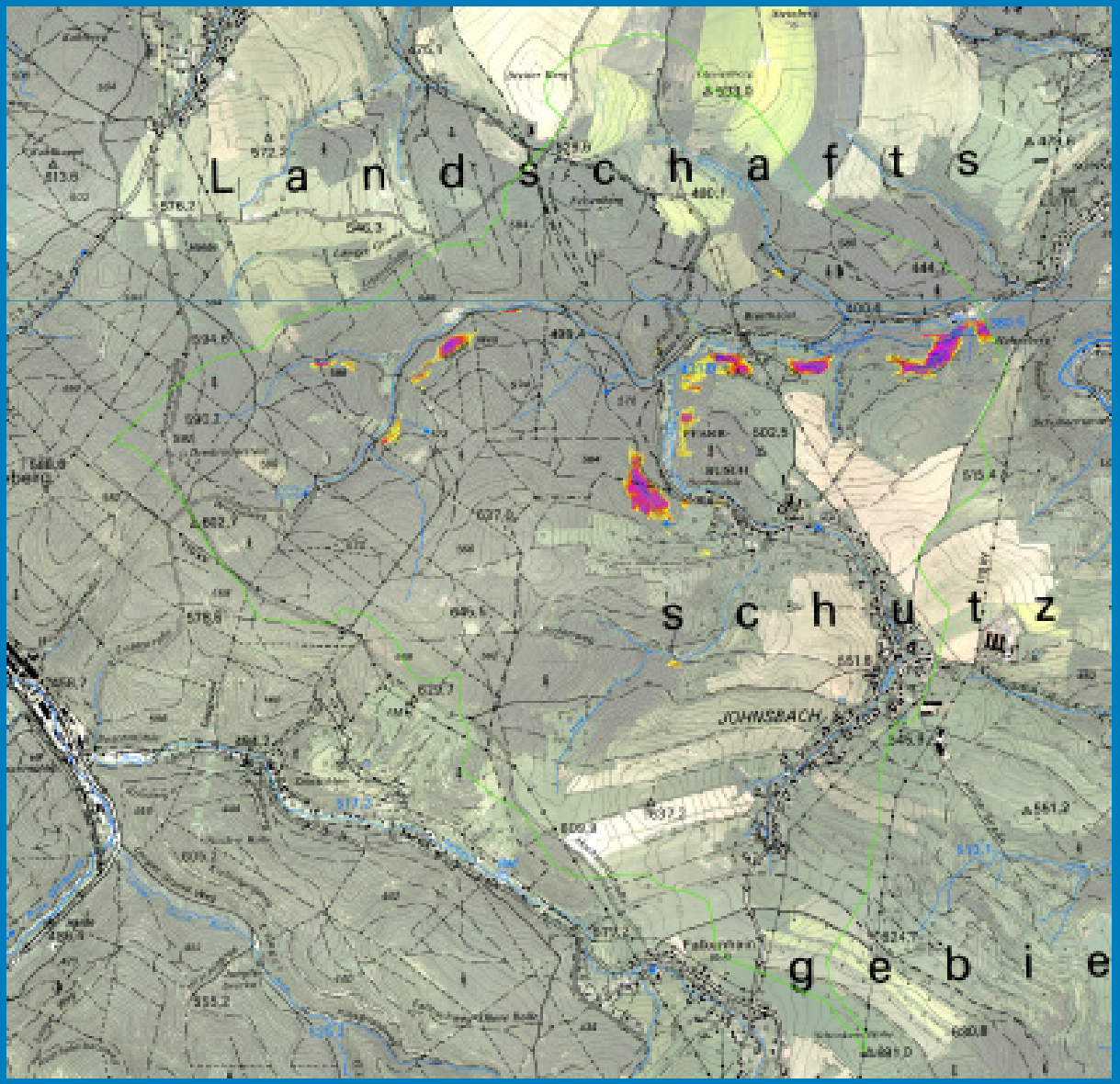
Training Data

Known Areas with Soil Creeping



Probability Modelling Results 3: Soil Sliding / Creeping



Legende

Arbeitsgebiet

Einzugsgebiet HRB Glashütte

HRB Glashütte

Dammkronenwasserspiegel (geplant: 408,20m üNN)

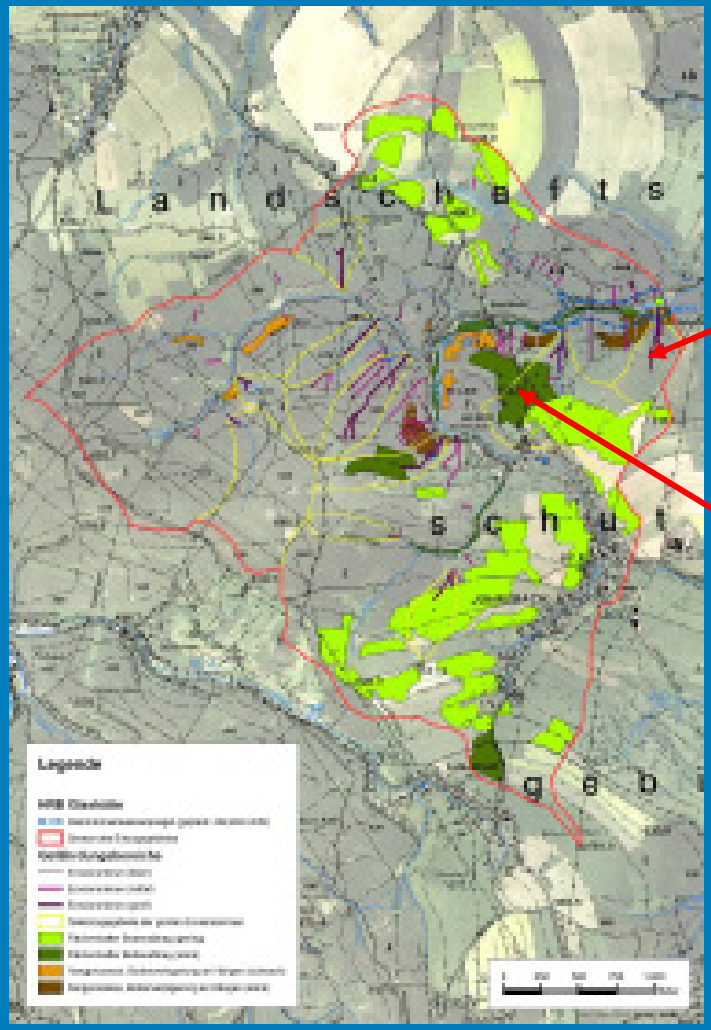
Gefährdung durch Hangprozesse / Bodenverlagerung an Hängen

Eintrittswahrscheinlichkeit

- < 55 %
- 55 - 60 %
- 60 - 65 %
- 65 - 70 %
- 70 - 75 %
- 75 - 80 %
- 80 - 85 %
- 85 - 90 %
- 90 - 95 %
- 95 - 100 %

Case Study : Glashütte Flood Control Reservoir Catchment Area

Delineation of Endangered Areas and Recommendation of Prevention Measures

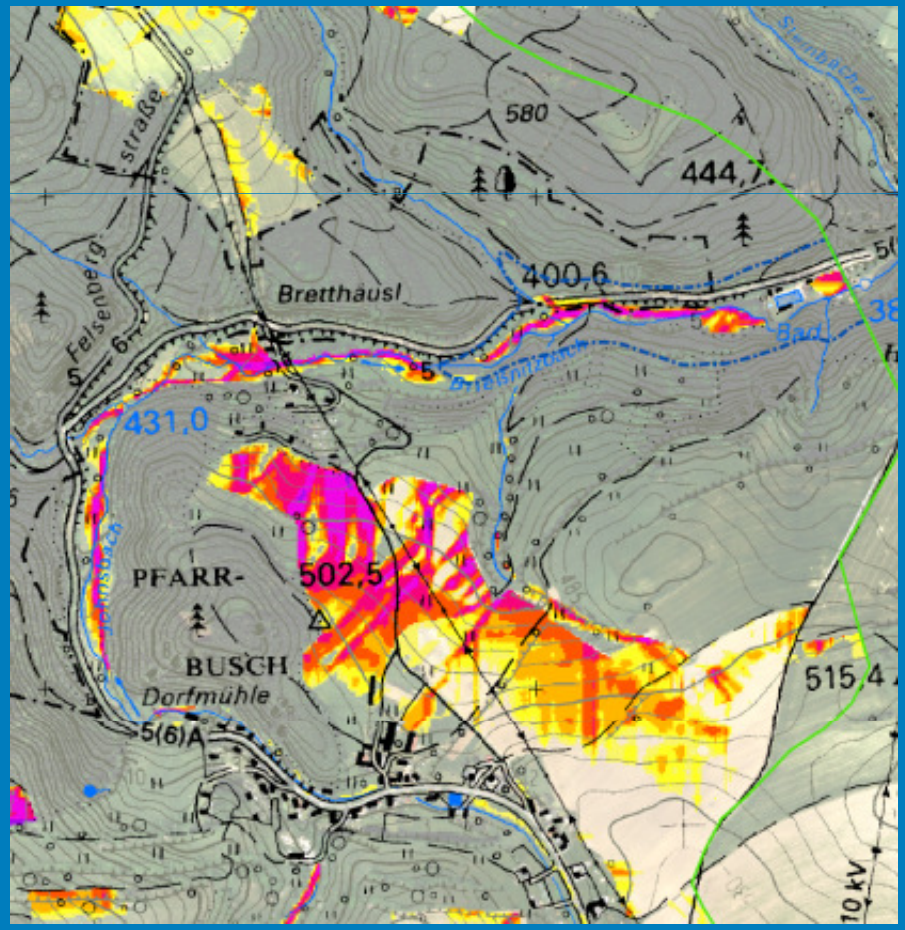


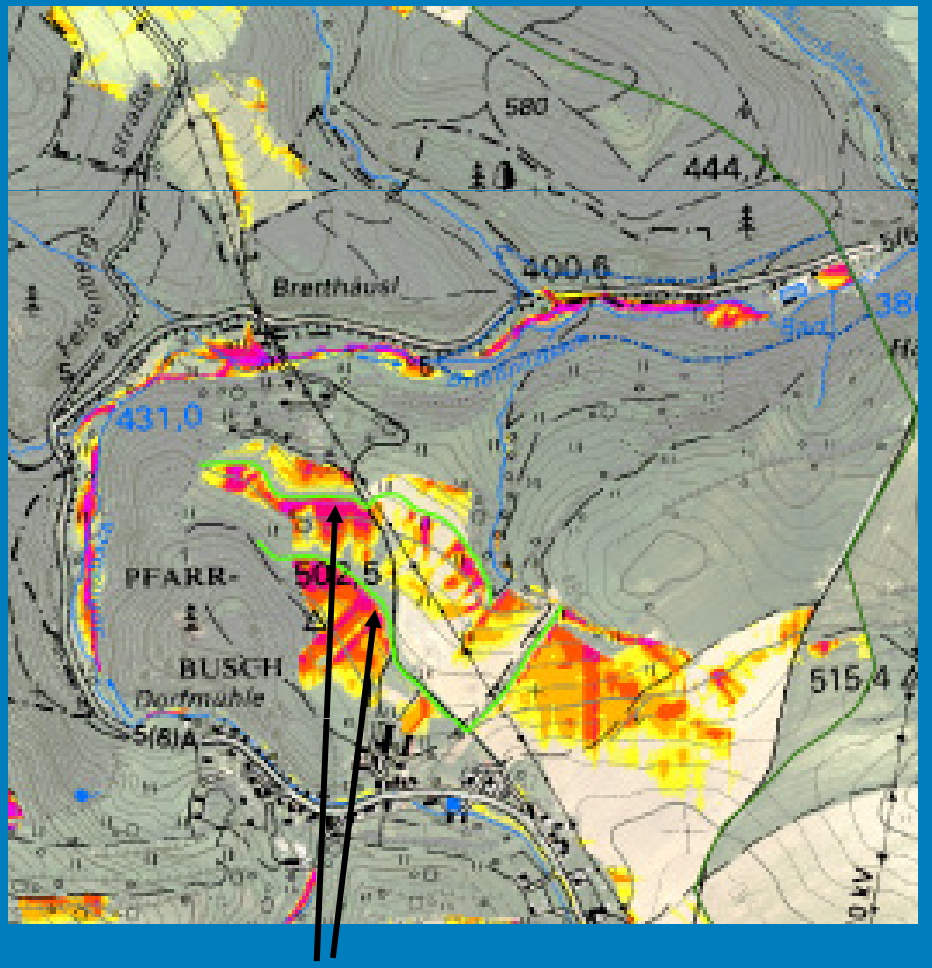
Bolder barriers against erosion gullies

Stone ridges against extensive soil erosion

Case Study : Glashütte Flood Control Reservoir Catchment Area

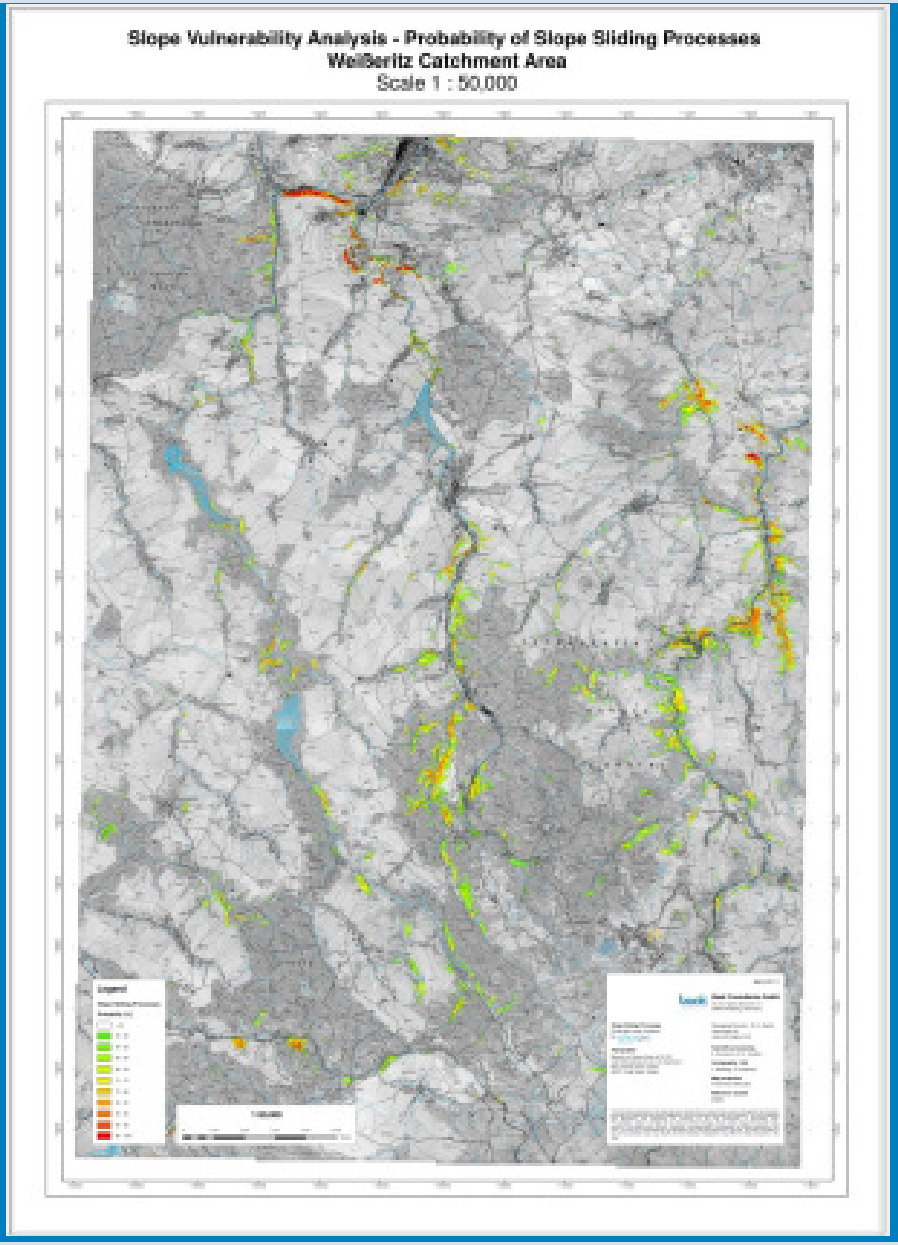
Modeling of Recommended Prevention Measures





Stone ridges against extensive soil erosion

Model Application: Weißeritz Catchment Area



Further Case Studies

- **Soil Creeping, Formation of Erosion Gullies**: Freital / Germany (2009)
- **Extensive Soil Erosion**: Weißeritz Catchment (2008)
- **Erosion Gullies**: Limpopo Area / South Africa (2009)

- **Coal Fires**: China (TUBAF, 2010)
- **Manganese Nodules Coverage Density**: Clarion-Clipperton Zone / Pacific Ocean (BGR, 2010)
- **Mineral Deposits / Occurrences - Pb/Zn, Au, Cr**: Kosovo (ICMM, 2003 – 2009)
- **Mineral Deposits / Occurrrence – Au**: Ghana (GSD, 2008)
- **Regolith Classification**: Burkina Faso (Universite Toulouse, 2010)
- **Soil Contaminations in Urban Areas**: Marienberg / Germany (LfULG, 2010)
- **Spread of Forest Pests**: Tharandter Wald / Germany (Sachsenforst, 2009)

- **Soil Geochemistry**: Brasil (TUBAF, 2011)
- **Mineral Deposits / Occurrences – Sn, W**: Erzgebirge (TUBAF, 2011)

Summary: Application of Artificial Neural Netwroks

- Multiple applications of the developed methodology using artificial neural networks and GIS for the **prediction of geo-hazard**

- **Currently in development:**
  - Soil Parameter Regionalisation Model
  - Mineral Deposit Prediction Model
  - ArcGIS 10 Support

→ **We look forward to your questions, suggestions and comments and hope for future knowledge sharing and collaboration!**

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