

# The Hydrogeological Risk as a potential tool for landform morphographic heterogeneity prediction in forestry exploration

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## ABSTRACT

ArcGIS software was used for individualization of landform morphographic heterogeneity in five (5) different mountainous broadleaf forest areas from Basilicata region, located in South Italy. Regional hydrogeological risk was based on defence plan for hydrogeological risk (Watershed Authority of Basilicata Region). It was considered as good prediction feature of landform morphographic heterogeneity for timber harvesting operations and new forest road construction for timber extraction. Orographic characteristics, such as slope, watershed systems features, and other natural obstacles were considered. The regional law and forest management plans as constraints for timber extraction were also considered. The analysis allowed identifying forest areas with high landform morphographic heterogeneity, and orographic or watershed restrictions to be considered in the planning and timber extraction optimization. This methodological approach should be tested in other mountainous forest regions subjected to slope instability.

**Keyword:** Hydrogeological risk, Landform morphographic heterogeneity, Timber harvesting, New forest road construction, Law and forest management plan constraints

## 1. INTRODUCTION

The GIS is a software technology that allows you to locate and analyze objects and events that occur on the earth, while the Italian SIT (Territorial information system) is a set of hardware

technology components, software and human resources capable to process, store, analyze and integrate spatial data to produce information for the government and management of the territory (Masoni et al., 2005). There are various software technologies used based on GIS, as well as experiences within forestry sciences based on the management of digital territorial data (Pira and De Natale, 1999) that were used to access road infrastructure network in the forest (Scrini et al. 1999).

Usually, the landform morphographic heterogeneity (accidental nature of the ground) is defined as the presence of natural obstacles (river presence, hollows, protruding rock) that difficult human transit and vehicles movement in the forest. Normally, the landform morphographic heterogeneity increases with the land slope (Hippoliti, 1994).

In this study a further territorial constraint is proposed, hydrogeological risk, which in the opinion of the authors, could have a significant impact in the Forest Management Planning. Regional law and forest management plans constraints were also considered.

By combining and analyzing information from orographic type, hydrographic network, and hydrogeological risk, cartographic models of analysis can be processed aimed to identify, site by site in the forest, the landform morphographic heterogeneity constraints. These affect the new traffic road planning for timber extraction operations, improving rationality in relation to the land conformation features and the “natural obstacles” (territorial constraints) present in the area.

The main goal of this study is to optimize the timber extraction in Appennine mountainous areas with the aid of geographic information systems (GIS). This approach was developed for new road construction in timber extraction sector within five forested areas in the province of Potenza, Basilicata region, Italy.

## **2. MATERIALS AND METHODS**

The five studied forest areas are Regional Forests belonging to the province of Potenza, Basilicata region in Italy: Bosco Grande Forest, Grancia Forest, Fossa Cupa Forest, Lata Forest, and Rifreddo Forest.

In the forest utilization planning, there are factors not editable, especially territorial, such as slope, hydrographic network and hydrogeological risk that do not allow the optimization of the forest timber extraction and new road construction, which is a key factor for forest management. These three layers of information, as well as the legal constraints were used to build the cartographic model presented. All GIS analysis were performed using ArcGIS 10 (ESRI, 2011).

## 2.1 Slope analysis

The slope analysis was performed using the DEM (Digital Elevation Model), which has been processed with the Spatial Analyst Tool "Slope", and was then reclassified as percentage considering five classes according to Hippoliti (1994): 0-20%, 21-40%, 41-60%, 61-81% and > 80%. The upper classes distribution were analysed and its incident area calculated for each forest, as shown in Figure 1.

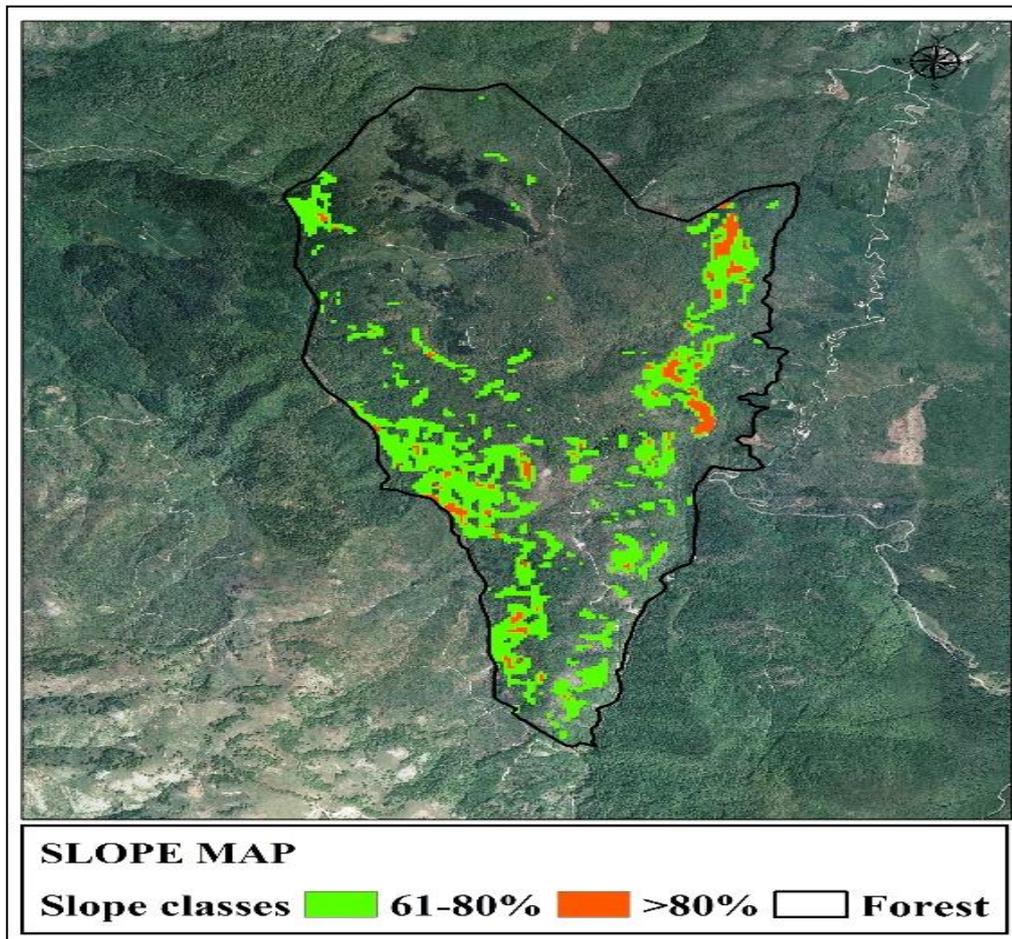


Figure 1: Ortophoto of Basilicata region from Fossa Cupa forest - example of slope classes calculated with Spatial Analyst tool "Slope", above 60%.

The slope gradients influence the new roads construction in forests, in fact land slopes above 60% were not considered for road construction, being considered as territorial constraints, for the forest road planning in the timber extraction.

## 2.2 Hydrographic network analysis

This analysis focused on the rivers presence in the forests, and their influence on the timber harvesting operations and new roads construction, in the same five different wooded area of the Lucano Apennines.

A shape file has been constructed for determination of river surface incident on entire forest surface.

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The shape file was made by editing the hydrographic layer of Basilicata region government, and adding the rivers (seasonal river) not present on it, by digitizing over a map IGM 1:25.000 and the Ortophotos of Basilicata region, as shown in Figure 2.

The river surface has been calculated building a buffer with 15 m width. This parameter is a measurement average of the rivers width with the aid of ArcGIS measurement tool, by photo interpretation.

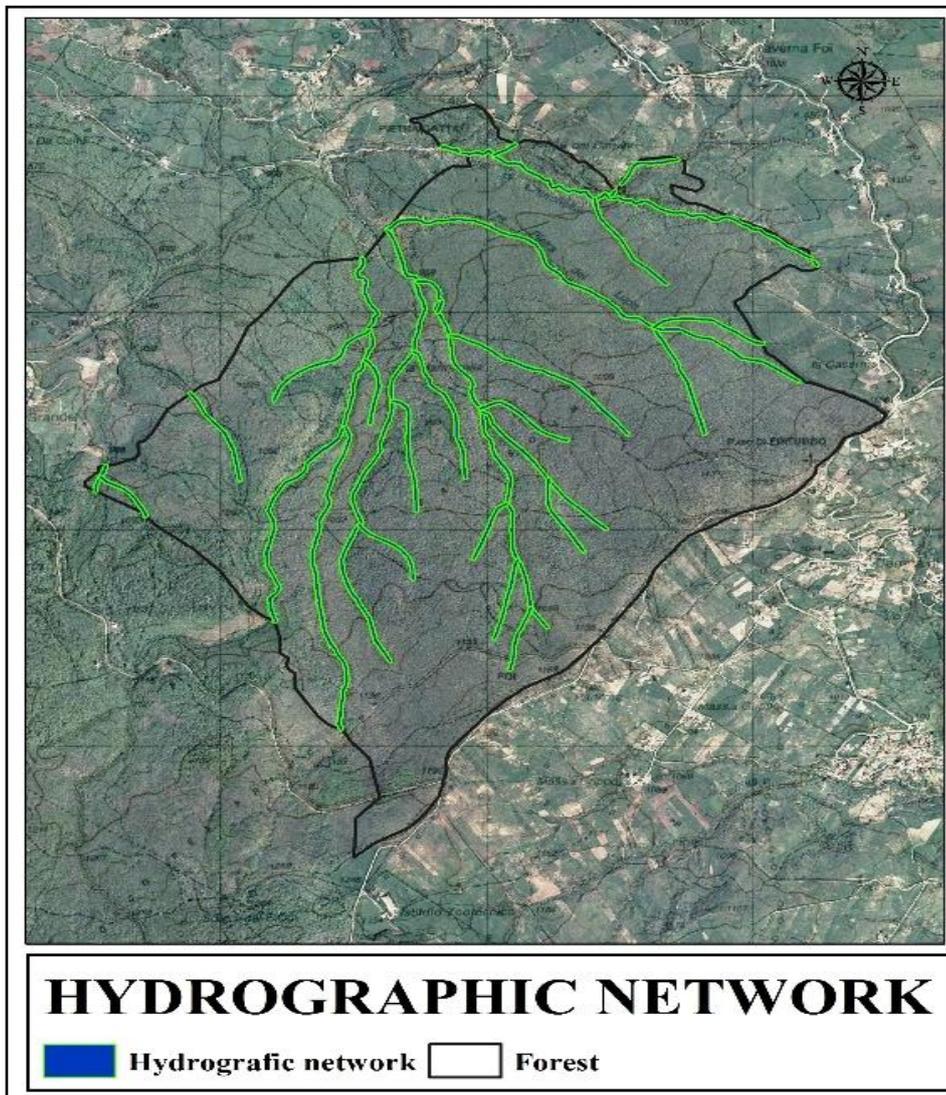


Figure 2: Ortophoto of Basilicata region from - example of hydrographic network and added stream in Bosco Grande forest.

### 2.3 Hydrogeological risk

The hydrogeological risk analysis was conducted using a reference layer downloaded from the website of Watershed Authority of Basilicata Region (Autorità di Bacino Regione Basilicata, 2013). The shape file was clipped for each forest, with Arcgis Geoprocessing Tool “Clip”, and then it was calculated its incident area on each forest. The risk was classified in four classes according to Watershed Authority of Basilicata region (2013), R1, R2, R3, and R4, as shown in Figure 3.

The Hydrogeological risk classification is:

- R1 = Area where it is possible the establishment of phenomena involving social and economic damage to the marginal environmental and cultural heritage;
- R2 = Area where it is possible the establishment of phenomena involving minor damage to buildings, infrastructure and environmental heritage, which do not affect the economic activities and the practicability of the buildings;
- R3 = Area where it is possible the establishment of phenomena involving risk to the safety of persons, functional damage to buildings and infrastructure, the disruption of socio-economic activities, damage to the environment and cultural heritage;
- R4 = Area where it is possible the establishment of phenomena which may cause loss of human life and / or serious injury to persons, severe damage to buildings and infrastructure, damage to the environment and cultural heritage, the destruction of socio-economic activities.

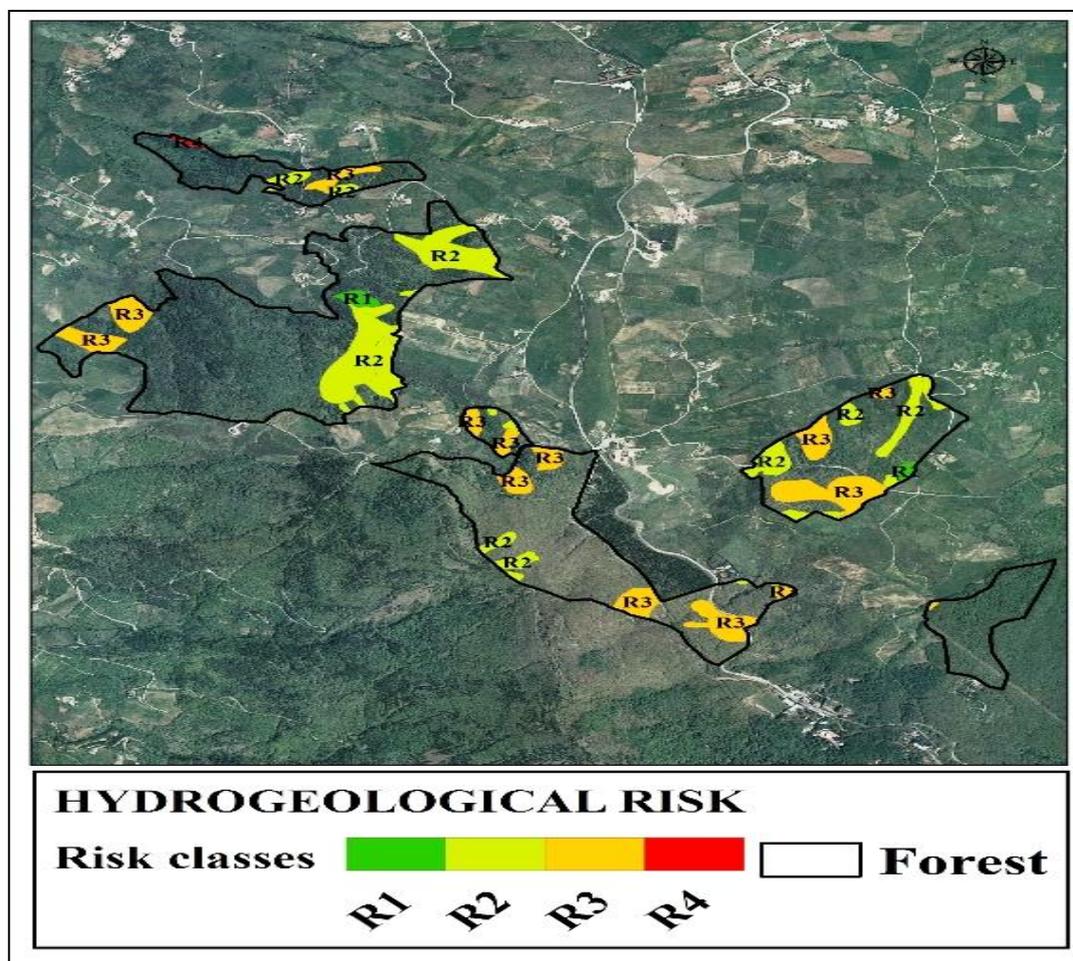


Figure 3: Ortophoto of Basilicata region from - example of hydrogeological risk presence, in Rifreddo forest.

## 2.4 Law constraints

Legislative constraints were also considered. In fact, starting from the Basilicata Regional Law

42/98, rules on forestry, art. 16, it is clear that the provisions relating to determination, exclusion

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and exemption of land in respect of hydrogeological restrictions, the rules and procedures laid down in R. D. 3267/1923, the R.D.L. 1126/26 and subsequent amendments and additions. The bounded area determination, in accordance with Title I, Chapter I, Section I, of the R.D. 3267/1923, must be preceded by a general recognition in the case of land included in a catchment area, in order to determine the hydrogeological conditions of it and the prevalent forms of land use and the included forests.

The Basilicata region government forest management plan restrictions were also considered. The main function of forest plans considered include that forests have two functions: production function and soil protection function, (Regione Basilicata, 2004). The operations of timber extraction and new road construction cannot be applied on the forest land under hydrogeological restrictions.

### **3. RESULTS AND DISCUSSION**

The proposed methodology allowed the identification of the areas having different territorial constraints within forests.

The impact of each constraint is based on the percentage of the total area that it represents (Table 1).

The results obtained from the spatial analysis showed that the hydrogeological risk in some areas is a real landform morphographic heterogeneity constraint. In fact, as shown in Table 1, the hydrogeological risk is present, especially, in Rifreddo forest (41 ha, 22%) and in minor amount in Grancia forest (22 ha, 5%), while in other forests it is absent (Fossa Cupa forest) or present in minor amount. The analysis of the other two territorial constraints showed that slope constraint has a bigger impact in Fossa Cupa forest (116 ha, 22% area forest), while in other forests as a minor importance (Lata Forest) or is even absent.

Hydrographic network covers all the forests. The main problem that hydrographic network creates for the new road construction, it is not the total hectares, but its disposition in the forest, in fact, often it has a fan shape that covers almost the entire forest area, as shown in Figure 2.

In fact, the forest managers need information about the potential impacts of roads on large areas to conduct cumulative effects analyses and watershed analyses for planning new road construction, and maintenance (Luce et al., 2001; Switalski et al., 2004).

The Figure 4 shows the effect of landform morphographic heterogeneity constraints on the new road construction proposal for the timber extraction. As it can be seen, in the blue circled area the negative effect of the constraints on a hypothetical road construction is shown, leaving a large area totally without roads. The main problem which the spatial analysis shows is the connexions of all constraints, which cover a good part of forest area.

Table (1): Landform Morphographic Heterogeneity in 5 forests of Basilicata region

Forest Landform Morphographic Heterogeneity							
Forest Name	Forest area	Hydrographic network		Slope		Hydrogeological risk instability	
	ha	ha	%	ha	%	ha	%
Bosco Grande	472	30	7	0	0	8	2
Fossa Cupa	746	53	7	116	16	0	0
Grancia	456	22	5	0	0	22	5
Lata	755	52	7	11	2	5	1
Rifreddo	173	14	8	0	0	41	24

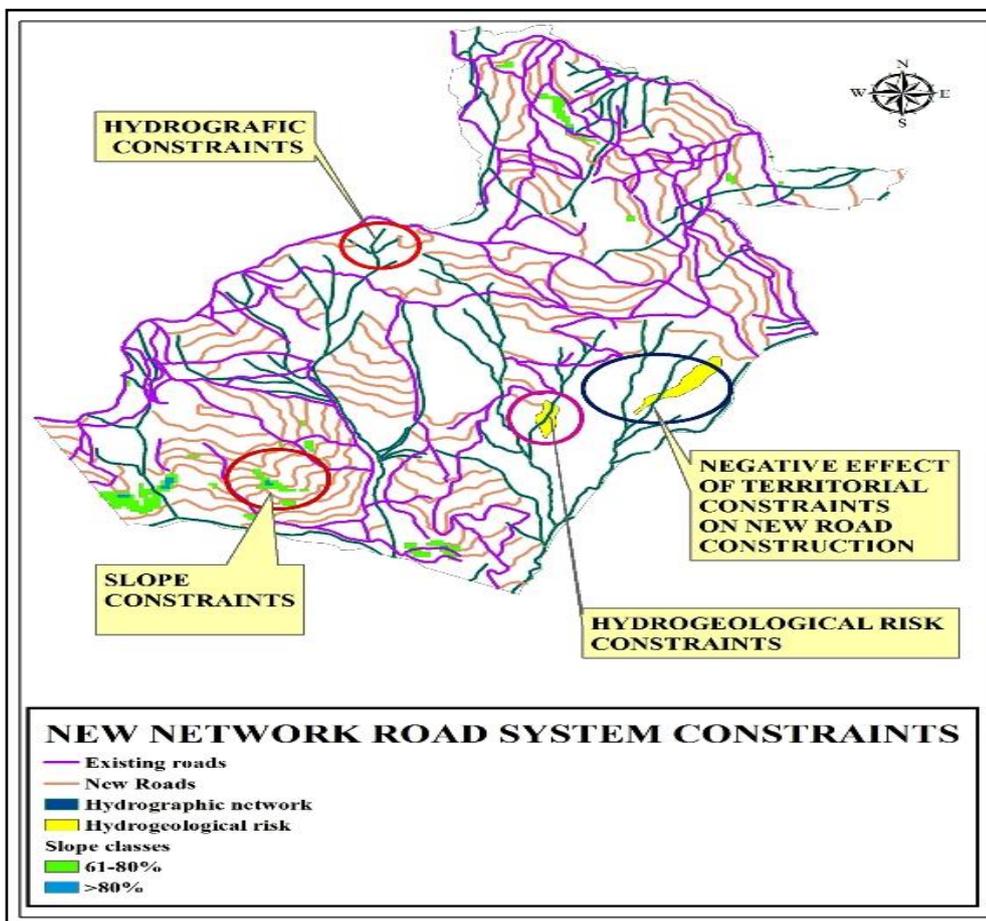


Figure 4: Example of landform morphographic heterogeneity constraints in Lata forest. Blue line limits an area with several constraints.

#### 4. CONCLUSIONS

The proposed analysis model allows to provide guidelines to identify a good planning strategy for new road construction in forest areas for timber extraction. In fact, the connections between

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territorial and legislative constraints do not allow to use and reach all forest points, for this reason it is desirable a prior spatial analysis, to improve forest planning (private or public), using advanced software systems, such as GIS tools, in order to optimize the work of forest companies (private or public).

## 5. REFERENCES

- Autorità di Bacino Regione Basilicata 2013. *Piano Stralcio per la Difesa dal Rischio Idrogeologico*. Cap. 4 pp 162-163, <http://www.adb.basilicata.it/adb/pStralcio/download.asp>
- ESRI, 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute
- Hippoliti, G. 1994. Le utilizzazioni forestali. Editrice CUSL, Firenze. pp 19-20, 22
- Luce, C. H. and T. A. Black. 2001. *Effects of Traffic and Ditch Mainenance on Forest Road Sediment Production*, The Seventh Federal Interagency Sedimentation Conference, Reno, Nevadad, March 25-29, 2001, p.V67-V74
- L.R. n. 42/98 . *Norme in materia forestale*. Art.16 ,vincolo idrogeologico.
- Masoni, M., Dibari, C., Siddi, E. 2005. *I Sistemi Informativi Territoriali. Provincia di Pisa*. [online] URL: [http://sit.provincia.pisa.it/sisterims/html/Corso\\_SIT/Corso\\_pagina\\_iniziale.Htm](http://sit.provincia.pisa.it/sisterims/html/Corso_SIT/Corso_pagina_iniziale.Htm)
- Pira, G., De Natale, F. 1999. *La gestione dei dati digitali territoriali nell'attività forestale. Alcune esperienze di programmazione come integrazione nell'uso dei GIS*. *Dendronatura* 2/99, Associazione Forestale del Trentino, Trento. pp. 34-37.
- Regione Basilicata. 2004. Forest management plan, Environment Italian Ministry, Basilicata region government, INEA, Forestry police
- R.D n. 3267/1923. *Riordinamento e riforma della legislazione in materia di boschi e di terreni montani*.
- R.D.L 1126/26. Approvazione del regolamento per l'applicazione del 30 dicembre 1923, n. 3267, concernente il riordinamento e la riforma della legislazione in materia di boschi e di terreni montani.
- Scrinzi, G., Picci, M., Floris A. (1999). *Analisi in ambiente GIS per la valutazione del grado di infrastrutturazione viaria delle aree forestali*. *Dendronatura* 2/99, Associazione Forestale del Trentino, Trento, pp. 63-73
- Switalski, T. A., J. A. Bissonette, T. H. DeLuca, C. H. Luce and M. A. Madej, (2004), *Benefits and Impacts of Road Removal*, *Frontiers in Ecology and the Environment*, 2(1): 21-28.