

THE MULTI-FUNCTIONAL ROLE OF FOREST ROAD NETWORK IN ITALY

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Abstract

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The role of forest tracks in forest maintenance, timber harvesting, fire fighting and recreational activities is becoming more and more important in Italy.

Good forest roads are crucial to effective forest management, and these activities all require the accessibility provided by a suitable road network.

The main aim of this paper is to provide a description of the multi-functional role of forest road network in Italy and to analyse the different aspects starting from logging operations, forest fire prevention and fighting and recreational activities.

In order to evaluate the accessibility to the forest, many cases study have been developed to describe particular forest areas.

Accessibility is the term used to describe the strip of forest reachable on foot by loggers or tourists from the nearest forest road and by the different types of vehicles used in forest fire fighting. The density of forest road network (m/ha) is an important parameter to highlight the forest areas where it is possible to carry out logging operations and where the fire fighting activity is possible according also to the availability of water points. The evaluation of the accessibility is not easy to realize especially when the extension of forested land is high, infact the trees have different features and the lay of the land often hinder the building of new roads. All these factors are useful to built a model played in GIS to get a decision support tool.

1 Introduction

For a long time the forest road network has the important function to simplify human activities aimed to exploit forests and to preserve the natural environment.

Many authors has already highlighted the main functions of the forest roads, in details these are:

- to simplify forest management, control, research and monitoring activities;
- to allow logging operations;
- to simplify the touristic use of forests;
- to allow forest fire prevention and fighting.

Planning is mainly important for public administration, with the aim to minimize the cost of forest operations in territories with severe management constrains.

In mountain environment of Central Italy, forests conditions are more and more difficult, both for the quantity and quality of wood products as for the management and maintenance of road network (Bortoli, 1998). These factors heavily influence the economic balance of forest management because of the cost of frequent extraction of small amount of wood on long distances, often low quality assortments, and the cost of forest road network maintenance (road surface, shoulder, logline, escarpment, manhole) continuously worn out by traffic and water runoff (Gaddo, 1972, Pettenella, 1998).

Road network planning, when it is done with classical techniques, is a difficult process. It often provides inadequate results, particularly when detailed morphological and orographic information of the forest district are required.

In this study the different functions of the forest roads are considered separately.

The execution of logging operations depends essentially to the availability and to the state of maintenance of the forest road network. Forest tracks should be planned and designed to respond to all necessity of the men and the forest.

Forest tracks designed without care and with lack of maintenance don't help for a good forest management. Infact a lack of attention in logging operation and in road building are the first cause of degeneration of many forested areas.

Nevertheless the building of new forest roads is considered very dangerous because of the impacts on the natural environment.

In the last years in Italy there is an increasing interest towards forest roads, but often the opinions are contrasting.

A first effort to plan the forest road network on a large scale was made in the 1970 by the Autonomous Province of Trento, the aim was to determine the forest road network density and distribution as a function of the needs of the different stands.

Since 1977 in Italy with the Regional management of forests, the importance and the interest on the forest road network has been different Region by Region (Cielo,2003).

Consequently the Italian forest road network has shown heterogeneous features.

This study highlight the current state of the qualities of the forest road network, allowing a cartography evaluation of the accessibility: which areas are "road served" and what is the road density.

The forest road network represents the starting point of forest operation planning. In fact, accessibility to the forest is a basic condition for forestry works execution (Bernetti, 1965; Fabiano et al., 1992; Hippoliti, 1976, 2003; Potočnik et al., 2005; Lugo et al., 2000; Weintraub et al., 1976) and it is a primary assumption for a rational management of forests, respecting the natural ecosystems (Cielo, 2003; Gumuse et al.,2007).

Forest accessibility analysis is fundamental for forest management and influence the planning of logging operation.

Using G.I.S. is it possible to evaluate forest accessibility from different point of view: logging operation, fire fighting and prevention and touristic aims. G.I.S. is an important instrument that should be integrated in the whole planning and management process.

2 Italian primary forest road network

The Italian primary road forest network considers roads with artificial or improved road surface, accessible for lorries or tractor and trailer used for timber transport, as well as normal or 4 wheel drive cars or vans for personnel transport. It must have stable characteristics over time and it must be permanent through periodical maintenance. The primary road network is an essential support for a reliable forestry and for appreciating the many services that a forest can provide, while the secondary forest network is strictly related to the logging activity (Hippoliti 1976, 2003).

The knowledge of all the features of the road network in a forest district is essential for the road network planning.

The primary road network has defined patterns regarding carriage width, slope and minimum curve radius, according to timber transportation requirements and site orography. According to those patterns we may distinguish "truck roads" and "tractor roads" (table 1). Also the spatial distribution of those roads must be optimal in order to enhance the environmental-economic compromise.

		Truck road		Tractor road
		Primary	Secondary	
Carriage width	minimum (m)	3,5	3	2,5
	prevailing (m)	5-6	4-5	4-6
Slope	optimal average (%)	3-8	3-9	3-10
	maximum av. (%)	10	12	14
	maximum short stretches (%)	14	18	20(25)
	maximum opposite directional (%)	10	12	14
Minimum curve radius (m)		10	7	5

Table 1 – Italian primary forest roads classification (Hippoliti, 1976)

The theoretical density of a road network, expressed in meters over the forested area (m/ha) as a function of slope, is an effective mean to evaluate the road distribution in a territory. In flat terrain and low-medium slope (0-40%) it is required a minimum road density of about 20-25 m/ha, on steep terrain (>40%), it is required a minimum of 30-35 m/ha density (Hippoliti, 2003; Hruza, 2003; Peters, 1978). But the density of a road network is not a good indicator about the forest road distribution on a forest district area.

The administration, or the technician in charge of the road network plan, must also accomplish with the requirement of accessibility in the meaning of a service provided by the road to the forested area. A “served forest” is the part of the forested area where according to fixed parameters, logging operations are convenient (Hippoliti, 1976). This necessity must be motivated by the forest management plan according to logging requirements and/or other economic goals.

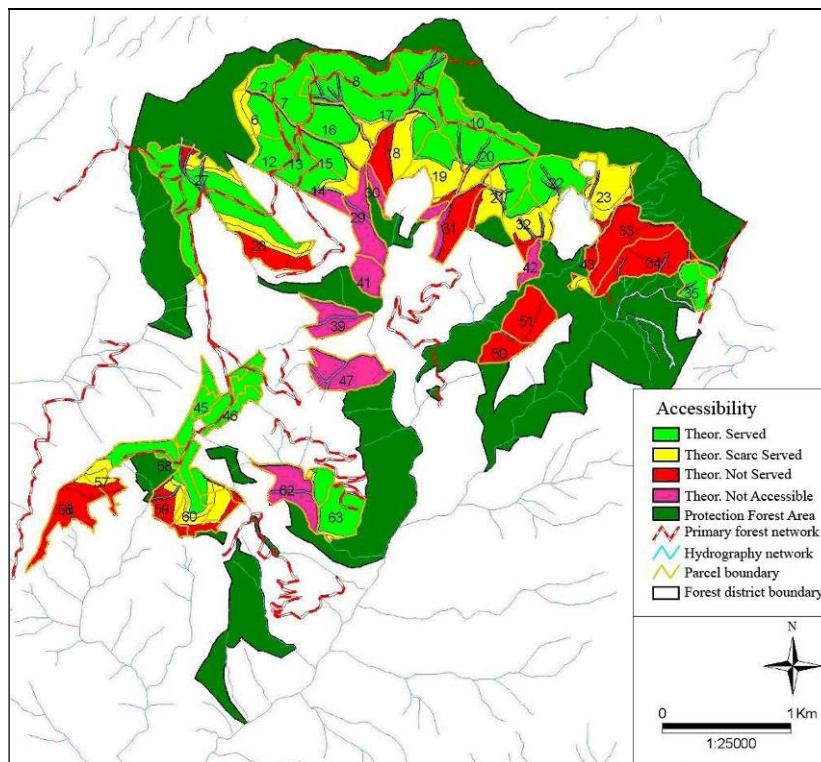
2.1 Accessibility determination in logging

The spreading of studied methodology, relying on GIS environment, allows to analyse accessibility according to new approaches.

To determine and to evaluate accessibility of forested areas was used a particular model: *Pixel Theoretic Time Travel Index (P3TI)* (B.Montorselli, 2008).

2.1.1 Pixel Theoretic Time Travel Index model

This models is based on the calculation of the parameter “pixel theoretical time travel” as a function of slope (Chirici et al., 1998, 2003; Forrow et al, 2001; Tan, 1992) where the concept of “maximum normal time of forest accessibility” (Hippoliti, 1976) as been developed.



Map. 1 – Example Pixel Theoretic Time Travel Index model accessibility map

This is a commonly used criterion, defining forest areas “road served” if it is possible to reach it within 15 minutes, or in 30 minutes round trip, by walking from the closes road loading the equipment and tools. This time represent about 6% of the whole working day. This methodology is adapted to the requirement of a better flexibility for accessibility calculation (Forrow et al., 2001; Tan, 1992), namely a subjective and dynamic interpretation that could be spread with a better reliability over the terrain characteristics (morphology, vegetation) and could refer also to other parameters (tourist use, wild fire control, etc.) (Chirici et al., 1998, 2003). The theoretic buffers of “served forest” will be pointed out on the maps by the pixels with values lower than 15 minutes (i.e. 900 seconds). The theoretic buffers of “not served forest” will be shown by the pixels with values higher than 30 minutes (i.e. 1.800 seconds). This model returns a forest accessibility map, namely a map of “served” zones and areas requiring accessibility.

3 Forest tracks and fire – fighting

Generally, fires are related to human activities and need an effective fire prevention and suppression organization, based on a deep knowledge of the territory, fire behaviour and suppression system resources network. To organise monitoring, prevention and fire fighting operations, it is important to know the risk level for different areas.

Ignition depends on a very large number of parameters, which should be analyzed simultaneously and fire events are heavily influenced by the characteristics of the territory, the meteorological factors and the fuel conditions.

In fire fighting activity the mobility and the speed of intervention of the land team are guaranteed by the availability of land vehicles, but often the forest road network results inadequate (Sulli et al., 1995a,b).

A good distribution of forest road network simplify control operation and fire prevention and they allow the direct attack to the fire front and the following extinction operation.

Moreover they are essential for the functioning of other infrastructures usually used in fire fighting, like towers, repeaters and water points and tanks, simplifying the access and

maintenance reducing time of intervention and optimizing extinction operation (Calvani et al, 1999; Croizer et al., 1975; Rodriguez y Silva, 2000; Spargi, 2005b; Sulli et al., 1995a,b). Finally forest roads represent an interruption of the vegetable fuel, so they often hinder the advancement of the fire front (Calvani et al,1999).

This forest road network is divided into 3 different class depending on the features of the vehicles usually used in fire fighting (Spargi, 2005a, Calvani et al, 1999, Sulli et al., 1995a,b; Hippoliti,1976, 2003):

- **Class 1** : primary tractor track less than 2,5 m wide with limited practicability suitable for class 1a vehicles
- **Class 2** : primary tractor track and tractor road more than 2,5 m wide with medium practicability suitable for class 1a and 2a vehicles
- **Class 3** : high practicability forest and truck road suitable for class 1, 2 and 3 class vehicles.

The evaluation of the forest road network density (linear metres of roads on land surface) is a very important aspect to be considered. Nevertheless the evaluation of the forest road network density in fire fighting activities should be connected to the other functions of forest roads. (Calvani et al, 1999)

De Montgolfier (1989), to determine the road network density correlates the maximum distance among tracks to the length of the fire front that can be attacked by the fire fighting operators directly on tracks: 25 m/ha on areas with high fire risk, 12,5 m/ha in those areas with a medium-high fire risk; 6,25 m/ha in areas with a low fire risk.

Considering all these factors forest road network planning in fire fighting and prevention activities should examine first of all those areas where the fire risk is high improving all the fire fighting system (Calvani et al., 1999), including the distribution of the infrastructures on the ground which often play the most important role.

3.1 Accessibility determination in firefighting

To evaluate the probability that a forest fire occurs and to organise prevention and management of fire fighting activities, both simple and easy-to-use risk and operational difficulty indices were implemented.

The operational difficulty index in fire fighting (ODIF) (Marchi et al., 2006), resumes all the factors affecting fire fighting activity by air and by ground, and suggests the extinction efficiency of forest fires in a given area.

The fire risk index processes different parameters to generate two hazards: static and dynamic, merged to obtain a Global Risk Index (GRI) (Conese et al,2004). It is very helpful to estimate the probability of forest fire occurrence, but it does not provide information on forest fire extinction difficulties.

Global Risk Index and ODIF are then integrated to give a more complex model FRI (Final Risk Index), thus improving the fire prevention planning, focused to the needs of a public operative structure. (Bonora et al., 2007)

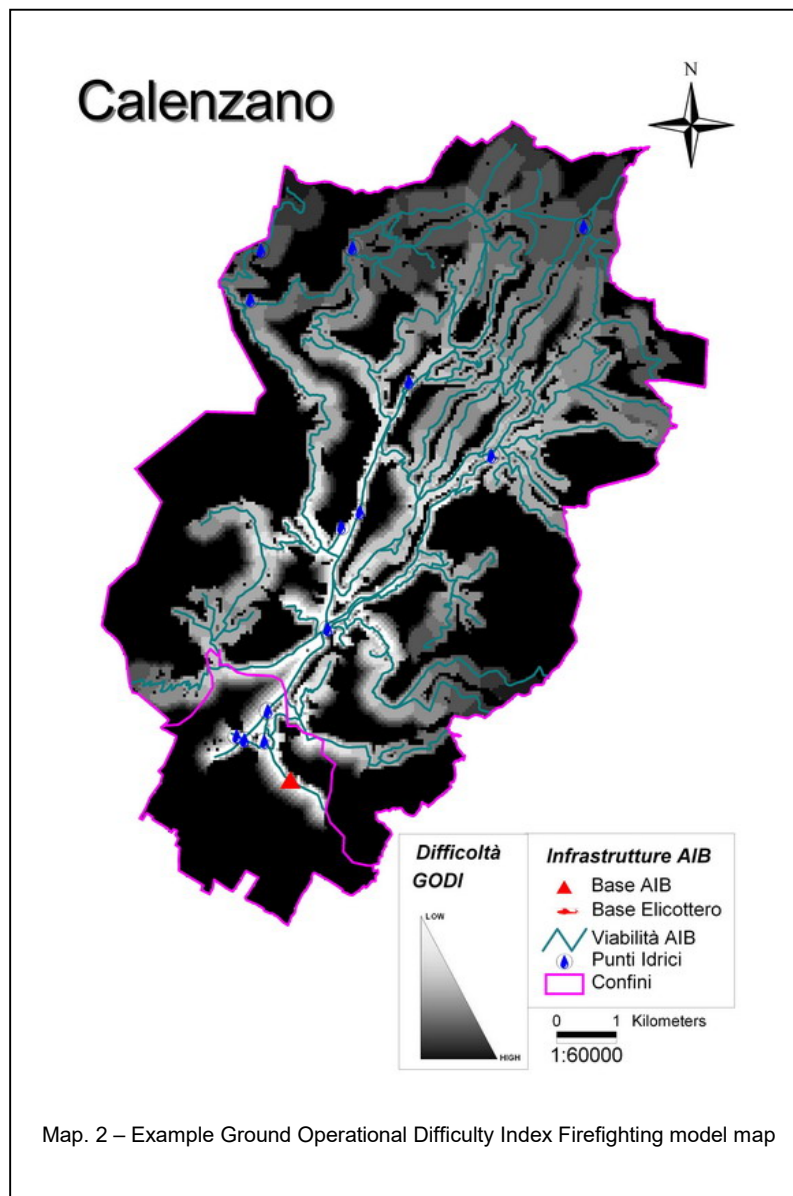
The ODIF analyses the road network, the water points distribution, the types of fire engines and the number and types of fire crews. The final result is an estimation of the efficiency and effectiveness of the fire fighting organization in a determined area. The first variables, that concern the initial attack efficiency, are determined by the estimation of the distances run to reach the different forest areas by different fire engines and helicopters:

In particular the **GROUND OPERATIONAL DIFFICULTY INDEX (GODI)** is depended from the characteristics and position of the fire fighting road network.

GODI is the result of the analysis of three components:

- VAT (vehicles access time) determines the efficiency in initial attack
- VST (vehicles supply time) determines the difficulties in water refuelling
- FOD (fire fighters operational difficulty) describes the difficulty for fire fighters to reach the burning area from the closest road. It define like the hydraulic potential fire fighting cars.

The ODIF model evaluates the efficiency of the forest road network for fire fighting giving important information for the infrastructures management.



4 Touristic use of forest

Since tourism could be considered as a further resource for mountain territories (de Bona A, 2005) the evaluation of the weight of the forest road network as regard touristic aims and the infrastructures planning is becoming more and more important (A.A., 2000).

The most important factors which could be useful to build a model for planning and to manage forest from the touristic point of view are (Chirici et al.,2003).:

- Forest road network: the recreational and touristic value of a road can be described as a function of the traffic intensity that it can support. A very important feature is the road signals that could increase the road value.
- Distance from public roads and car parks: recreation is more widespread near public roads and car parks.
- Presence of touristic infrastructures: the most of tourists use to go near bars, hotels and restaurants.
- Notable sites: areas with a special value because of their landscape and natural beauties.
- Use of the soil class: as a function of the treatment of the forest.
- Ground slope: low ground slope forest are more appreciated by tourists.
- Anthropic areas are not appreciated by tourists (quarries, power lines, dumps, etc...

These information are the inputs of many models that evaluate the importance of the touristic use in a particular forest site. In Italy there are many important and different forest sites with different treatments needs: the Alps, Apennines and rural areas, ect.

4.1 Accessibility determination in the evaluation of the touristic use of forest

The most suitable model for the many forest realities in Italy should consider the relations between all the factors just described. The recreational and touristic value should be determined considering the presence or the lack of infrastructures. The aim is to represent in an algebraical form the relations between all the factors analyzed.

Moreover the most important factor to be consider is the touristic interest for the forest: infact a forest could be accessible but no tourists couldn't have any interest in it, so it is fundamental to evaluate the importance of a road as a function of the touristic interest.

The weight of all the factors is evaluated by means of interviews to the population (Pettenella,2000).

5 Conclusion

In order to fulfil the goals of the forest management plan, forest logging, fire-fighting and recreational needs must be planned. Because their beneficial, results in the economic and environmental sphere, could be soon only on long-terms time.

The elaboration and analysis of the Forest Road Network Plan is thus a basis of the forest logging, fire-fighting, recreational request planning.

The aim of the work is to explain the Italian level experimentation model to plan Forest Road Network Plan.

The Forest Road Network Italian situation in each region is not homogeneous and that difference influence the local forest management.

To make a Forest Road Network Plan is important to evaluate the forest request in logging, fire-fighting, and recreational, no less, their relation. The model to determine the accessibility in the meaning of a service provided by the road to the forested area. A "served forest" is the part of the forested area where according to fixed parameters, logging operations, fire-fighting operation and recreation request are convenient. So to enlarge the term develop by Hippoliti (1976) for logging.

The accessibility is determined by the particular fuzzy algorithms run in GIS:

- ❖ For the logging operational is been considered a closest forest road loggers time travel ;
- ❖ For the fire-fighting operational consider the time travel from the fire-fighter point of departure, time travel between the water point and the average closest forest road operative figh-fighter powerfully.
- ❖ For the recreational request is been considered a closest forest road tourist time travel over forest path.

It is important to realize a evaluation Forest Road Network Plan mixed the three principal analysis factor and the forest district administrator can use the results like a DSS tool to improve the his forest management.

Other aim of the work is to be a development begin to DSS tools that grow and improve in the future. So that important to continue the study about this important forest management analysis form.

6 Reference

- A.A.,2000 - "Allegato A: METODOLOGIA PER LA REDAZIONE DEI PIANI DI GESTIONE FORESTALE", Piano di sviluppo rurale 2000-2006; Regione Umbria
- Bernetti G., (1965) "La rete stradale forestale come problema di assestamento", L'Italia Forestale e Montana, - Fasc. n.6, Firenze, pp 261-267
- Bernetti I, Severino R., 2007 – "Economia delle risorse forestali" Liguori Editore Srl pp 448-464
- Bonora L., Brachetti Montorselli N., Checcacci E., Marchi E., Romani M., Tesi E., 2007; "An operational tool for fire management and fire prevention planning for public administration (Tuscany region-Italy)"; Wildfire 2007 - 4th INTERNATIONAL WILDLAND FIRE CONFERENCE. Spain 2007
- Bortoli P.L., (1998) "La viabilità per la valorizzazione delle aree protette e della selvicoltura naturalistica", Atti Convengno Internazionale U.N.I.F. "Viabilità Forestale: Aspetti ambientali, legislativi e tecno-economici", Lago Lacero (AV),(1998), Ed. A.G.R.A. s.r.l., anno 2001,Roma, pp 101-128
- Bovio G., 1993. – "Comportamento degli incendi boschivi estinguibili con attacco diretto".Monti e Boschi 44, 4, 19-24.
- Brachetti Montorselli N., (2008) "GIS tools analysis for forest roads network planning" 2008 May 26 - 30, 2008, Dorint Don Giovanni Hotel, Prague, Czech Republic www.fortechenvi2008.org Scientific Programme 3rd International Scientific Conference
- Calvani G, Marchi E., Piegai F., Tesi E., 1999 - "Funzioni, classificazione, caratteristiche e pianificazione della viabilità forestale per l'attività antincendio boschivo"; L'Italia forestale e montana, maggio-giugno 1999.
- Canter, L. W., y L. G. Hill. 1981 - "Handbook of Variables for Environmental Impact Assessment - Ann Arbor Sci. Pub"
- Carriero A., Scrinzi G., Tabacchi G., Tosi V., Weger W.; 1998- "GARDEN: procedura di integrazione tra GIS e sistema esperto per la stima del valore turistico-ricreativo degli ambienti naturali"; Comunicazioni di Ricerca ISAFSA 97/2, Trento
- Chelazzi C., Brachetti Montorselli N., (2008) "Leggi regionali e viabilità forestale" III Congresso Nazionale di Selvicoltura 2008, Taormina (CT)
- Chirici G, Marchi E, Rossi V.; Scotti R; 2003; "Analisi e valorizzazione della viabilità forestale tramite G.I.S.: la foresta di Badia Prataglia (AR)"; L Italia Forestale e Montana, n° 6/03
- Chuvieco, E., Salas, F.J.,Carvacho, L., Rodriguez-Silva, F., 1999 – "Integrated fire risk mapping", in E. Chuvieco (ed.), Remote Sensing of Large Wildfires. New York: Springerverlag.
- Cielo P., (2003) "La viabilità agro-silvopastorale. Elementi di pianificazione e progettazione"; Ipla - Istituto per le piante da legno e l'ambiente, Regione Piemonte
- Conese C., Bonora L., Romani M, Checcacci E.; 2004 – "Forest fire hazard model definition for local land user" (Tuscany Region)
- Croizer R., Crouzet Y., 1975 - "L'infrastructures routière. Les incendies des forets. Numero spècial de le revue forestière francaise". Tome 2, pp. 552.

de Bona A, 2005 - "Selviturismo: proposta di turismo alternativo." *Forest@ 2* (3): 273-274.
[online] URL: <http://www.sisef.it/>

De Montgolfier J., (1989), "Protection des foret contre l'incendie. Guide technique du forestier mediterraneen." Fiches n. 9 CREMAGREF, Division Techniques Forestieres Mediterranee

Fabiano F., Marchi E. (1991) "Pianificazione della viabilità forestale"; Atti del seminario UNIF: " Il bosco e i suoi valori: esperienze e prospettive per la pianificazione forestale", 14-15 novembre 1991, Brasiamone (BO): 196-201.

Gaddo M., (1972) "Alcune considerazioni sulla convenienza alla costruzione delle strade a servizio de bosco", *Economia Trentina*, pp, 1209-1216

Gumus S., Hulusi A.H., Toksoy D. (2007) "Functional forest road network planning by consideration of environmental impact assessment for wood harvesting" *Journal Environmental Monitoring and Assessment*, Springer Netherlands ISSN 0167-6369 (Print) 1573-2959 (Online) DOI 10.1007/s10661-007-9912-y *Earth and Environmental Science*

Hippoliti G., (1976) "Sulla determinazione delle caratteristiche della rete viabile forestale", *L'Italia Forestale e Montana*, Anno XXX- Fasc. n.6, Firenze, pp 242-255

Hippoliti G., (2003) "Note pratiche per la realizzazione della viabilità forestale", *Compagnia delle Foreste*, Arezzo

Hrůza P.,(2003) "Optimisation of forest road network under principles of functionally integrated forest management", *JOURNAL OF FOREST SCIENCE*, 49 (9): pp 439–443

Jenks G.F.,Caspall F.C., 1971. Error on Choropletic maps: definition, measurement, reduction. *Annals of the Association of American Geographers*, 61, 217-244.

Lugo A.E., Gucinski H., (2000) "Function, effects, and management of forest roads" *Forest Ecology and Management* Volume 133, Issue 3, Pages 249-262

Marchi E., Tesi E., Brachetti Montorselli N., Bonora I., Checcacci E., Romani M., (2006); "Forest fire prevention: developping an operational difficulty index in firefighting (ODIF)";. V International Conference on Forest Fire Research D. X Viegas (Ed.).

Pettenella D., Urbinat C., Bortoluzzi B., Fedrigoli M., Piccinini C.; (2000) "Indicatori di gestione forestale sostenibile in Italia"; *Rapporto Finale della Ricerca Affidata al Dipartimento Territorio e Sistemi Agro-Forestali dell'Università di Padova Serie Stato dell'Ambiente 11/2000*

Potočnik I., Yoshioka T., Miyamoto Y., Igarashi H., Sakai H., (2005) "Maintenance of forest road network by natural forest management in Tokyo University Forest in Hokkaido" *Croatian Journal of Forest Engineering* Vol.26 No.2

San-Miguel-Ayanz, J., 2002, Methodologies for the evaluation of forest fire risk: from longterm (static) to dynamic indices, in *Forest Fires: Ecology and Control*, Anfodillo T. and Carraro, V. (Eds), *Forest Fires: Ecology and Control*, Univesity degli Studi di Padova, pp. 117-132.

San-Miguel-Ayanz, J., Barbosa, P. M., Schmuck, G. , Libertà, G., 2003, "The EuropeanForest Fire Information System (EFFIS), 2003, Joint International Workshop of EARSeL

SIG on Forest Fires and the GOFCC/GOLD-Fire Program: Innovative Concepts and Methods in Fire Danger Estimation, held in Ghent (Belgium) on 5-7 June 2003.

Sulli, F.; Marchi, E. (1995)(a) ; “Classificazione degli automezzi per l’antincendio boschivo impiegati in italia (prima parte)”. Sherwood Compagnia delle Foreste (AR)1, 39-43.

Sulli, F.; Marchi, E. (1995)(b) ; “Classificazione degli automezzi per l’antincendio boschivo impiegati in italia (seconda parte)”. Sherwood Compagnia delle Foreste (AR) 2, 39-45.

Viegas X, Bovio G, Ferreira A, Nosenzo A, Sol B.; 2000 – “Comparative study of various methods of fire danger evaluation in southern Europe”. International Journal of Wildland Fire 9, 235-246.

Weintraub, A., Navon, D., (1976). “A forest management planning model integrating silvicultural and transportation activities”. Management Science 22 (12), 1299-1309.

Spargi B., (2005)(a) ; “Gli autoveicoli anticendio” – “Incendi boschivi” – a cura di Marchi E. e Zanzi Sulli A. – Comportamento, effetti ecologici, prevenzione e sistemi di lotta. – Università degli studi di Firenze, Regione Toscana.

Spargi B., (2005)(b) ; “La rete idrica” – “Incendi boschivi” – a cura di Marchi E. e Zanzi Sulli A. – Comportamento, effetti ecologici, prevenzione e sistemi di lotta. – Università degli studi di Firenze, Regione Toscana.