Forest Policy and Economics 92 (2018) 106–118

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

# A GIS-based model for multiscale forest insurance analysis: The Italian case study

Sandro Sacchelli*, Maria Cipollaro, Sara Fabbrizzi

*GESAAF, Department of Agricultural, Food and Forest Systems Management, University of Florence, 18, P.le delle Cascine, I-50144 Florence, Italy*

ARTICLE INFO

*Keywords:*
Risk management
Timber value
Hazard probability
Spatial analysis
Insurance premium

ABSTRACT

The increasing probability of natural and human-induced extreme events in forests calls for innovative forms of risk management. Insuring timber is one possible way to cope with possible financial damages incurred by forest owners. This study developed a Geographic Information System (GIS) for identifying optimal insurance schemes in the forestry sector. The model comprises three modules used to calculate: i) potential financial damage (temporary or permanent), ii) the annual probability of extreme events (fires and storms), iii) the insurance premium for each site. Research focused on a multiscale approach able to provide outputs at a regional (NUTS-2) and national scale in Italy. Results reveal the high variability of forests in the case study area from the standpoint of both the value of woodlands and the probability of extreme meteorological events. In general, premiums seem to be consistent in the southern regions, in high forest and in Mediterranean forest typologies. The model can be used to analyse different scenarios and variables related to forest characteristics/management as well as financial options. Additional analysis can reveal where and how public subsidy of insurance premiums could favour the diffusion of this form of risk management.

## 1. Introduction

In recent decades forests the world over have had to face increasing hazards. Storms, fires, snow, fungi, beetles and other anthropogenic as well as biotic/abiotic factors have damaged timber stands (Schelhaas, 2008). Predicted climate scenarios suggest that there will be an increase in extreme and anomalous events that can pose a threat to forest sites (IPCC, 2012). Possible impacts are strongly differentiated according to the probability of occurrence, geographic context and magnitude (Lindner et al., 2008). Several studies have focused on adaptation strategies as risk control measures for sustainable forest planning and management (see e.g., Schoene and Bernier, 2012). Different silvicultural options, combinations of forest species and spatial diversification are suggested regional and local strategies for coping with climate change (Lindner et al., 2014).

Financial intervention is another form of risk management in the case of forest hazard. In this sense, the most common strategy for coping with damage due to extreme meteorological events or impacts is public refunding of forest restoration expenses (Brunette et al., 2015). This measure not only enables the reestablishment of wooded areas but also the restoration and maintenance of forest ecosystem services (Barreal et al., 2014). A limitation of ex-post public funding is that it provides aid to forest owners only in emergencies, with financial disbursements of up to several millions of euros per event. This creates a temporary economic overload for public bodies. Alternative measures, such as forest management activities, forest insurance or a combination of these, may not be adopted when public bodies provide financial assistance for natural disasters, as demonstrated in various studies (Brunette and Couture, 2008; Sauter et al., 2016).

Forest insurance could be a valid strategy for addressing the risk of forest hazards. Stand insurance, which protects owners against economic losses (Deng et al., 2015) and allows stabilization of income (Qin et al., 2016), can be considered a risk control strategy for coping with uncertain, risky environments (Dai et al., 2015). A worldwide survey by Zhang and Stenger (2014) revealed how the percentage of private landowners who have forest insurance differs among countries. New Zealand and China have the greatest number of insured private stands (55% and 50%, respectively). In Chile this form of protection reaches 60% of “planted” forest, whereas market penetration seems to be lower in other countries (13% in South Africa, < 10% in Japan and 3% in the United States). European countries also differ in the level of insurance coverage. The Scandinavian region has the oldest tradition of forest insurance. One of the first fire insurance schemes was developed in Norway in 1898. Norway, Sweden and Finland have a long history of forest landowners associations, which are able to assist negotiations between individual landowners (mainly Non-Industrial Private Forest –

* Corresponding author.
*E-mail address:* sandro.sacchelli@unifi.it (S. Sacchelli).

https://doi.org/10.1016/j.forpol.2018.04.011
Received 27 October 2017; Received in revised form 26 April 2018; Accepted 27 April 2018

**Nomenclature**

| | |
|---|---|
| A | Factor to calculate the pixel area (ha/pixel) |
| C | Regeneration cost (€/ha) |
| CLC | CLC-th forest typology |
| e | Yearly costs (€/ha $y^{-1}$) |
| E | Number of extreme wind events per year |
| f | Forest area damaged by fire per year (ha) |
| FEV | Expected forest value (€/ha) |
| g | g-th regions |
| i | i-th pixel in raster maps |
| m | Age of thinning (years) |
| n | Age of forest (occurrence of damage – year) |
| P(F) | Yearly probability of fire damage (%) |
| $p(F)_{CLC,g}$ | Yearly probability of fire in the CLC-th forest typology belonging to the g-th region |
| $p(F)_g$ | Yearly probability of fire in the g-th region |
| P(W) | Yearly probability of wind damage (%) |
| $P(W_0)$ | Base yearly probability of wind damage (%) |
| q | 1 + r |
| r | Interest rate (%) |
| R | Restoration cost (€/ha) |
| S | Stumpage value of final harvest (€/ha) |
| s | Percentage of damaged forest surface (%) |
| SV | Salvage value (€/ha) |
| T | Stumpage value of thinning (€/ha) |
| t | Rotation period (years) |
| TD | Temporary damage (€/pixel) |
| v | Yearly income (€/ha $y^{-1}$) |
| $w_{CLC}$ | Factor to weigh the CLC-th forest typology according to the probability of wind damage |
| x | Number of pixels with positive Expected Stand Value |
| y | y-th year of analysis of extreme wind events |
| z | Analytical period for extreme wind events (years) |
| α | Number of fires |
| δ | Total forest area (ha) |
| ε | Risk coefficient for premium quantification (%) |
| λ | hypothesis of insured forest in respect of total surface with positive Expected Stand Value (SEV) (%) |
| σ | Variable management costs sustained by the insurance company |
| θ | Percentage of premium rate funded by public bodies (%) |
| χ | Total fixed cost sustained by the insurance company (€/y) |

NIPF – landowners) and insurance companies. Sweden has the highest percentage of NIPF area covered by insurance (95%), followed by Finland (40%) and Norway (35%). The insurance penetration rate is high in northern European nations, including Denmark (50% of the area). Other countries seem to encounter more problems in the diffusion of forest insurance. France and Germany, for example, insure 6% and 5% of NIPFs, respectively (Brunette and Couture, 2008). In Spain only 1.25% of insurable forests are covered by an insurance scheme (Agroseguro, 2011).

There are different reasons for the low level of forest insurance coverage in some countries. Based on the summary of the Confederation of European Forest Owners – CEPF – Insurance day (CEPF, 2010), one reason could be the lack of marketing activity. Few forest owners have an accurate understanding of forest insurance mechanisms and availability. This is partially due to highly fragmented forest ownership, especially in the Mediterranean area, and the lack of owner associations. Insurance activity is rarely associated with the forest sector (1% globally). Risk management strategies are lacking in insurance companies because reinsurance – that is insurance purchased by an insurance company from one or more insurance companies – is uncommon in the forest sector (CEPF, 2010). An additional problem highlighted by CEPF is the scarcity of reliable and validated models for quantifying risk, timber/forest value, and potential damage to woodlands. From a policy perspective, insuring forests is generally a lower priority than insuring agricultural lands, although an increasing interest in this area emerges from EU documents (see e.g. the guidelines of “The EU Strategy on adaptation to climate change” and “The Green Paper on the insurance of natural and man-made disasters”, implemented as part of the climate change adaptation Strategy package) (European Commission, 2013; Sauter et al., 2016).

In recent years a few models and studies have addressed the difficulties in applying forest insurance. Most have focused on potential demands for insurance. Brunette and Couture (2008) investigated how public funding can decrease both requests for insurance and adaptation strategies to extreme events. Brunette et al. (2014) also examined public compensation (including insurance subsidy) in combination with other factors. The authors determined the Willingness To Pay (WTP) for insurance among 42 private owners of non-industrial forests in the Aquitaine region. The risk of natural hazards and the trust in public intervention are important variables determining participation in the forest insurance market. WTP was examined in a Mississippi case study through the application of an interval-censored survival model and a Kaplan-Meier Turnbull nonparametric model (Deng et al., 2015). In the study, the WTP was lower than the premium currently charged by insurers, partially explaining the underinsurance of stands among landowners. Similar conclusions were reached by Sauter et al. (2016) in a study involving 137 German forest owners offered fire and storm insurance. In addition, the authors found that the WTP of owners seems to be influenced by subsidized insurance premiums but not by risk. Qin et al. (2016) investigated farmers' demand for forest insurance to identify important factors influencing the market and to suggest strategies for the diffusion of insurance coverage.

From the standpoint of insurance offers, studies have mainly tried to determine optimal premiums. Since pioneering investigation about the need of development for forest (fire) actuary (Brown, 1928) and discussion on main strengths as well as weaknesses of insurance schemes applied to forest (Wright, 1950; Shepard, 1950), different insurance tools have been developed. One of the first models to address this issue was implemented by Shepard (1937). The author proposed a framework to compute premium rate for fire insurance in the Pacific forests of United States. The premium is based on the value of stand (Douglas fir - *Pseudotsuga menziesii*, ponderosa pine - *Pinus ponderosa* Douglas –, sugar pine - *Pinus lambertiana*) and on the fire risk for different regions due to causative as well as conflagration factors for fires. Results defined an average premium rate of 0.45% of stand value.

A model by Holecy and Hanewinkel (2006) includes empirical probability functions as well as a nonparametric Kolmogorov–Smirnov statistical analysis to estimate forest destruction probabilities for a case study in the Southern Black Forest of southwest Germany. Holecy and Hanewinkel (2006) analysed the minimum premium, demonstrating how it varies greatly according to the insured surface and the stand age (from 0 €/ha $y^{-1}$ to 4429 €/ha $y^{-1}$). In order to make forest insurance business more appealing and familiar to forest owners Pinheiro and de Almeida Ribeiro (2013) implemented a simplified model to depict premiums to insure Portuguese forests from fires risk. Barreal et al. (2014) presented a model to simulate variability in profitability and rotation of coniferous stands in Galicia (Spain) due to the introduction of fire insurance. This paper went a step further than previous research in that it considered restoration measures in private forests. Brunette et al. (2015) proposed an actuarial model for multiple natural hazards insurance in a silver fir (*Abies Alba* Mill.) stand in Slovakia. The model considers different type of hazards (independent or dependent) and