Forest Policy and Economics 73 (2016) 239–250

Contents lists available at ScienceDirect

Forest Policy and Economics

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

# A local knowledge-based approach to predict anthropic harvesting pressure zones of wild edible mushrooms as a tool for forest conservation in Central Mexico

Sergio Franco-Maass [a], Cristina Burrola-Aguilar [b,*], Yolanda Arana-Gabriel [b], Luis Antonio García-Almaraz [a]

[a] Instituto de Ciencias Agropecuarias y Rurales, Universidad Autónoma del Estado de México, Instituto Literario 100, col. Centro, C.P. 50000 Toluca, Estado de México, Mexico
[b] Centro de Investigación en Recursos Bióticos, Facultad de Ciencias, Universidad Autónoma del Estado de México, Km 14.5, carretera Toluca-Atlacomulco, C.P. 50200 Toluca, Estado de México, Mexico

ARTICLE INFO

*Article history:*
Received 18 May 2016
Received in revised form 21 September 2016
Accepted 27 September 2016
Available online 4 October 2016

*Keywords:*
Ethnomycology
GIS
*Abies religiosa*
Multi-Criteria Evaluation
Policy

ABSTRACT

The aim of this study was to develop a model to estimate human pressure exercised through the process of harvesting mushrooms on the high mountain forest ecosystems of Central Mexico. To predict human pressure, we applied a local knowledge-based model to a Geographic Information Systems and Multi-Criteria Evaluation (GIS-MCE) approach. The study area was Nevado de Toluca, which is located in a mountainous forest ecosystem of the Trans-Mexican Volcanic Belt. To construct the model, we used cartography data (land cover map, digital elevation model [DEM], distribution of villages, roads and sidewalks) and local knowledge regarding mushroom harvesting (questionnaires, semi-structured interviews, field trips with mushroom harvesters). The level of pressure model was based on the application of the Weighted Linear Combination (WLC). Thus, harvesters were queried regarding the importance of the main criteria cited in the literature and whether they considered looking for the best harvesting sites. With the information generated, a multi-criteria image was obtained that expressed the potential harvesting pressure. The model was validated with real data from field trips. The location of harvesting sites was then compared with the level of pressure obtained with the GIS analysis model. The model demonstrated that proximity to fir (*Abies religiosa*) forests exerted a greater influence on the value of the obtained pressure level; moreover, this type of vegetation is preferred by the local people for harvesting mushrooms. The final human pressure map confirmed that the model closely reflected the behavior of the mushroom harvesters in the studied region, and it was applied considering the 23 villages within the protected region of Nevado de Toluca. The information obtained can be used to locate areas with increased harvesting pressure, to establish potential sites for mushroom production, to propose a special program that includes management policies with successive harvesting schemes, or to define priority areas for monitoring and conserving this type of non-wood forest products (NWFPs).



## 1. Introduction

Worldwide, the consumption of mushrooms has increased, of which marketing is a popular activity for rural communities to promote new revenue (Boa, 2004; Cai et al., 2011). After China, Mexico ranks second in the number of wild mushrooms traditionally consumed. There are 371 mushroom species which are considered as NWFPs (Garibay-Orijel and Ruan-Soto, 2014). They serve as food and have a high economic importance for rural communities who live near forests (Mariaca et al., 2001; Pérez-Moreno et al., 2008; Garibay-Orijel et al., 2009). The harvest of mushrooms is a social activity (Montoya et al., 2008) that is part of the bio-cultural heritage of the rural population and involves a strong sense of family and community bonding (Rodríguez-Muñoz et al., 2012). This activity represents a real alternative for sustainable forest management and generates significant environmental, economic and social benefits (Benítez-Badillo et al., 2013).

Some factors related to the harvest of mushrooms are the type of vegetation, abundance, distribution, accessibility, cultural importance, consumer preferences, assigned prices (Jarvis et al., 2004; Ruan-Soto et al., 2009), distance between forests and the town where they are marketed, demand, and income from sales (Montoya-Esquivel et al., 2002, 2003; Garibay-Orijel et al., 2007; Burrola-Aguilar et al., 2012). Local knowledge plays an important role in the selection of the harvest sites and collection route. The collection process starts with knowledge of the habitat of the fungi and their morphological characteristics. People use information transmitted by the elderly as well as their own experience, the phenology of species, environmental conditions (climate, soil and micro-topographical conditions), and tree species that are associated with the elevation of each gathering area, which influence the presence of fungi (Mariaca et al., 2001; Montoya et al., 2014).

* Corresponding author.
*E-mail addresses:* sfrancom@uaemex.mx (S. Franco-Maass), cba@uaemex.mx (C. Burrola-Aguilar), agyarana@hotmail.com (Y. Arana-Gabriel).

http://dx.doi.org/10.1016/j.forpol.2016.09.020
1389-9341/

On average, a mushroom gatherer walks in the forest for 4 h, between 8 and 20 km per day (Montoya et al., 2008), and includes more than 120 fruiting bodies in various locations. According to the different communities, collection patterns vary among harvesters and between men and women. Men travel longer distances at higher elevation, but they harvest fewer species and visit fewer collection sites. In contrast, women exhibit better performance and more easily adopt appropriate search strategies (Pacheco-Cobos et al., 2010).

Although harvesting is an important socio-economic activity, there are no reliable data to determine whether that activity threatens the mushroom populations. However, the effects of repeated harvesting on the forest habitat are unknown (Arteaga and Moreno, 2006). The expansion of the commercial gathering in many parts of the world, has led to reflect on the possible damage to the overexploitation of fungal resources. In spite of this, it has been found in systematic studies and long term, that constant and periodic harvesting not reduce the amount collected or the richness of species of wild mushrooms (Egli et al., 2006). In addition, the high value of wild mushrooms in the national and international markets has increased their collection from the temperate forests of Mexico, transforming their use from a level of self-consumption and local sales to commercialization on a larger scale. This expansion has generated a habitat disturbance, resulting in land degradation. For example, the removal of other organisms that interact with fungi, or disruption of the mushroom life cycle conducive a decrease the abundance and distribution of the populations of fungi (Alvarado-Castillo and Benítez, 2009).

According to Jasso-Arriaga et al. (2016), who carried out research on traditional knowledge and vulnerability of edible mushrooms in the Nevado de Toluca, they found that some harvesters who possess traditional ecological knowledge, argue that most of the habitats of mushrooms have disappeared mainly by activities such as irrational felling of trees, trampling, grazing and lack of moisture and organic matter in the forest. These are human activities that have contributed to the decline of 36 species of edible mushrooms in the region.

Therefore, it is necessary to implement sustainable development strategies, including knowledge of biology, ecology and productivity of wild edible mushrooms of cultural or economic importance to the people of the region (Ortega-Martínez and Martínez-Peña, 2008). For example, mushroom harvesters in Oaxaca, Mexico, have zoned their communally owned land to prevent timber extraction or other land uses from damaging mushroom collecting areas. They have also started training harvesters to avoid litter removal, which has a negative impact on production, and to recognize different quality grades (Belcher and Schreckenberg, 2007).

The Geographic Information System (GIS) has been a very powerful tool for the evaluation of NWFPs. Pilz and Molina (2002) proposed its use to estimate the production of edible mushrooms across a watershed or area of land. Yang et al. (2006) forecasted the habitat of matsutake mushrooms using logistic regression and a GIS expert system with environmental and stand parameters. Garibay-Orijel et al. (2009) proposed the use of a GIS to improve mushroom harvesting by the local communities on a commercial scale. Mumcu and Zeki (2015) developed a GIS program to create spatial distribution maps of *Lactarius deliciosus* and *L. salmonicolor* to prepare multi-purpose forest management plans that include NWFPs. The GIS-Multi-Criteria Evaluation (MCE) approach has been very useful for forest conservation planning (Phua and Minowa, 2005; Greene et al., 2010; Matsuura et al., 2014a) which applied MCE based on the analytic hierarchy process (AHP) and GIS to analyze the spatial characteristics of the habitat distribution of fern species, considering both natural and anthropogenic factors.

The integration of MCE with GIS involves the use of geographical data, the definition of decision-maker's preferences and the selection of a defined rule (Malczewski, 2004). The preferences usually depend on the knowledge of technical experts. Considering that NWFP harvest sites are generally influenced by both the ecological characteristics of each species, and human harvesting behaviors (Matsuura et al., 2014a), the knowledge of local forest harvesters can be very useful to determine the criteria and preferences involved in identifying harvesting sites (Matsuura et al., 2014b). Local expert knowledge adds value to science by providing detailed insights into local and regional environmental problems (Chalmers and Fabricius, 2007). It is important to consider that local pickers have long-term experience locating the

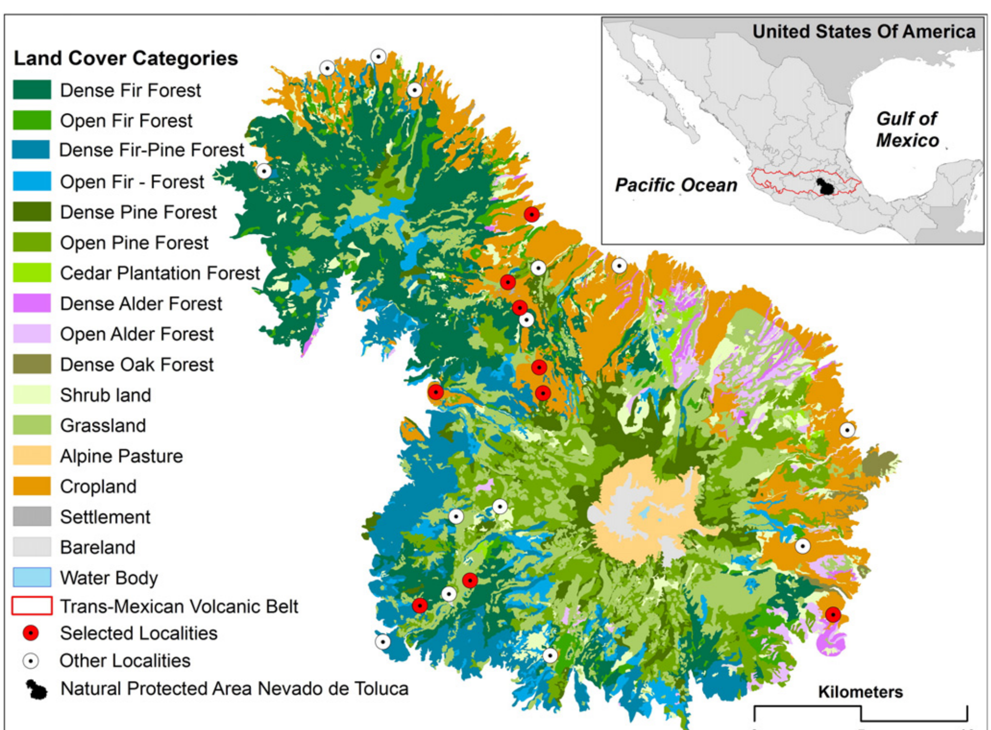


**Fig. 1.** Villages and land cover in the protected area of Nevado de Toluca.