# Fragmentation of the forests in Mexico: national level assessments for 1993, 2002 and 2008

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This paper presents the results of national level assessments of the fragmentation of temperate and tropical forests of Mexico in three dates: 1993, 2003, and 2008. In these assessments, the latest INEGI's homogenized land cover data-sets and a raster roving window method were used. Using a Geographic Information System (GIS), this method produces maps showing five classes of fragmentation of the remaining forest patches. Google EarthTM (GE) is used as a platform to provide access to this digital cartography over the Internet. It is argued that the cartographic results of this study are more informative than traditional numeric estimates of forest fragmentation. It is also argued that the ease of access and visualization capabilities available through GE better contribute to support strategic level planning of the forest areas at national level, as well as forest and environmental education of diverse end users and stakeholders.

**Key words:** Mexican forests, GIS, Google Earth, Fragmentation.

Este artículo presenta una estimación del nivel de fragmentación de los bosques templados y tropicales de México en tres fechas (1993, 2003 y 2008) usando las capas más recientes de uso del suelo y vegetación homogenizadas del Instituto Nacional de Estadística y Geografía (INEGI) y un método *raster* de ventana móvil. Utilizando un sistema de información geográfica (SIG), este método produce mapas con cinco clases de fragmentación de los manchones de bosques. *Google Earth* (GE) se usó como plataforma para distribuir y dar acceso a esta cartografía digital a través de Internet. Sostenemos que la cartografía digital creada en este estudio es más informativa que las estimaciones numéricas de la fragmentación de los bosques y que la facilidad de acceso y visualización disponibles a través de GE contribuyen de mejor manera a apoyar tanto la planeación a nivel estratégico de las áreas forestales a nivel nacional como  la educación forestal y ambiental dirigida a diversos usuarios.

**Palabras clave:** bosque de México, SIG, *Google Earth*™, fragmentación.

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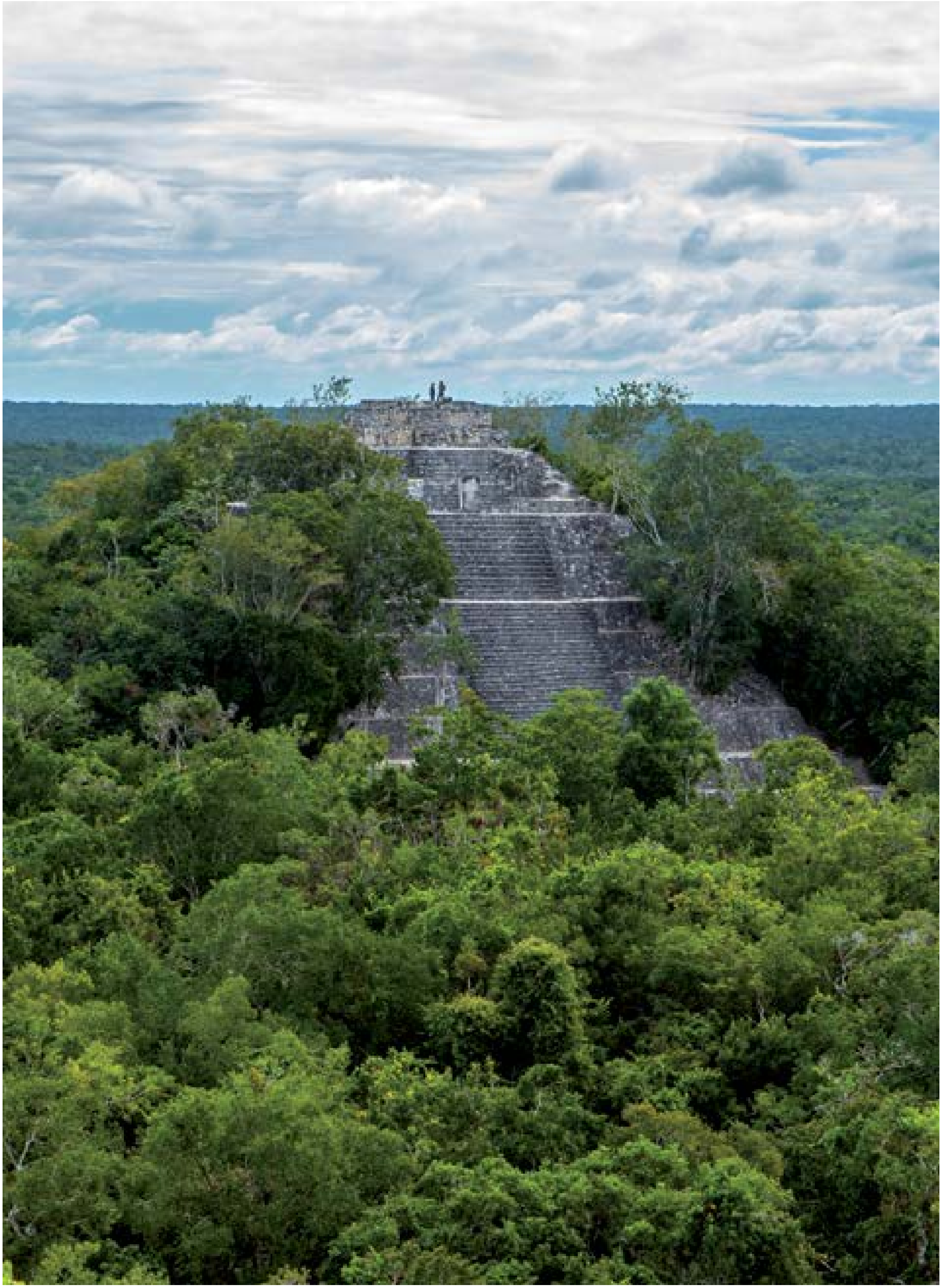


Ancient Maya City of Calakmul, Campeche, Pyramids Mexico©iStockphoto.com/ 123455543

## 1. Introduction

Historically, studies on forest characterization and evaluation have made emphasis on estimating deforestation rates and the extent of the remaining forests at the national and global levels (e.g. Matthews 2001, Achard *et al*. 2002, FAO 2010). Although this information is important for estimating the sustainability of forest ecosystems, equally important are the conditions of the remaining forests with regard to their ownership, composition, structure and spatial pattern.

Forest patches spatial pattern (estimated through different measures of fragmentation) is of particular importance in estimating the capacity of the remaining forests to produce goods and services, as well as to sustain critical ecosystem components and functions at different temporal and spatial scales (Lindenmayer et al. 2002, McAlpine and Eyre 2002, Garcia-Rigoro and Saura 2005, Kupfer 2006, Portillo-Quintero and Sanchez-Azofeifa 2009). This importance is recognized in international agreements for the conservation and sustainable management of forest ecosystems such as the FAO Global Forest Resources Assessments (http://www.fao.org/forestry/fra), the Millennium Ecosystem Assessment (http://www.millenniumassessment.org/en/index.aspx), and The Montreal Process (http://www.rinya.maff.go.jp/mpci/meetings_e.html) where "Fragmentation of forest types" is one of nine indicators of the criterion "conservation of biological diversity" (http://www.rinya.maff.go.jp/mpci/criteria_e.html).

Numerous studies have been published on the effects of forest fragmentation on specific plants, animals, or ecosystem processes at local and regional levels in Mexico (approximately 41 in the last 10 years e.g. Estrada and Coates-Estrada 1996 and 2002, Estrada *et al*. 1999 and 2006, Mas *et al*. 2000, Ochoa-Gaona 2001, Andersen 2003, Ochoa-Gaona *et al*. 2004, Cayuela *et al*. 2006a and 2006b, Galicia *et al*. 2008, Arroyo-Rodriguez *et al*. 2009, Saynes *et al*. 2012). When studies have been conducted at the national level, they have concentrated only on specific types of forests (e.g. Trejo and Dirzo 2000). These local and national level studies have not used a common methodology complicating comparisons of results across different times and scales. More recently two studies have assessed the fragmentation of the tropical and temperate Mexican at the national level (Moreno-Sanchez 2011 and 2012). However, since the publication of these studies new revised cartography of the forest cover at the national level has become available.

Recently, the National Institute for Statistics and Geography of Mexico (INEGI) revised and homogenized the classes for its land use and vegetation cover cartography corresponding to the years 1993, 2002 and 2008 (known as Series II, III and IV respectively). This process increases the capability to compare vegetation cover changes over time at national level. This paper presents an assessment of the fragmentation of the temperate and tropical forests at national level using this revised cartography. The purpose of the results generated in this study is to support: a) education about the changes on the extent and fragmentation of the temperate and tropical forests in the country; and b) forest conservation and management strategic level planning at national level.

The methods used in this study result in maps showing levels of forest fragmentation. These cartographic results are more informative than fragmentation metrics in tabular form with no spatial reference. To better achieve the purposes of this study, access to the resulting fragmentation level maps is provided as Super Overlays in Google Earth™ (GE) over the Internet. The rich contextual information (e.g. roads, local photos), recent-date satellite images, and spatial visualization features available through GE allow end users to explore the results dynamically at different scales and develop their own visual analyses without the need for local high-end computing and software technology.

The remainder of the paper is organized as follows: section two provides a brief background on forest fragmentation; section three and four present data sets and methods used in this study; section five presents the results of the analyses; section six discusses the results; and finally, section seven draws conclusions and recommendations.

## 2. Background on forest fragmentation

The topic of forest fragmentation, and more generally habitat fragmentation, is complex and has been extensively studied (Lindenmayer and Fisher 2006). It is the single largest subject of publications by conservation biologists (Fazey *et al*. 2005). A search using a scientific publications search engine (e.g. www.ingentaconnect.com) returns 151 publications on the subject just in the last two years worldwide. A review of this massive, multifaceted, and context-dependent topic is beyond the scope of this paper. Just two points will be highlighted next to provide background for later discussions.

First, there is ambiguity on what "fragmentation" is and what its effects are (Villard 2002, Groom *et al*. 2005, Lindenmayer and Fisher 2006). There are several factors that contribute to making the concept of habitat fragmentation vague and context dependent (Lord and Norton 1990, Murcia 1995, Haila 1999, 2002, Harrison and Bruna 1999, McGarigal and Cushman 2002, Villard 2002, Lindenmayer and Fisher 2006). Some of the factors that contribute to the complexity in defining fragmentation and its effects include: 1) habitat fragmentation consists of both reduction in the total area of the original habitat and change in the spatial pattern of what remains; 2) different single species, groups of species, and ecological systems experience and response to the degree of fragmentation of a particular environment in different, even contradictory ways; 3) numerous temporal and spatial scales must be considered, the relevant scales for different single species, group of species, ecosystem processes, geographic regions, and types of environments are likely to be different; 4) ambiguity on whether the focus of work is on either land-cover (e.g. a specific vegetation type) fragmentation in a landscape, or on fragmentation of habitat suitable for a particular individual species of plant or animal; 5) lack of focus on the processes and mechanisms underlying and giving raise to the emergent fragmentation patterns; 6) all natural environments are fragmented to some degree, and they are subject to continuous change due to natural processes; there is not yet a clear standard for assessing human-caused fragmentation; and 7) lack of consistency in study design and methodologies used to analyze habitat fragmentation makes comparisons, integration of information and results, and replication of studies difficult.

Second, although it is not easy to draw broad general conclusions regarding forest fragmentation and its effects, there is general agreement among scientists and forest managers of the need to quantify it and to integrate it into management plans and simulations that will assist us in better understanding the interactions among human activities, forest features, and ecological processes (Murcia 1995, Shugart and Smith 1996, Hargis *et al*. 1998, Debinski and Holt 2000, Santiago and Martinez-Millan 2001, Boutin and Herbert 2002, McGarigal and Cushman 2002, Rutledge 2003).

The historical, socio-cultural, demographic, economic and even institutional-political drivers of the deforestation and fragmentation of forests in Mexico is beyond the scope of this study. However, it is important to highlight their relevance for the effective conservation and management of the forests in the country. These drivers vary by location and type of forest ecosystem. The work by Klooster (2004), Bonilla-Moheno *et al*. (2012), Bonilla-Moheno *et al*. (2012b), and Bocco *et al*. (2001) provide insights into these factors and processes.

Previous studies of the fragmentation of the forests in Mexico at national level have used methods that result in numeric estimates of fragmentation parameters presented in tables without a spatial reference (Moreno-Sanchez *et al*. 2011) or have not used the most recently revised and homogenized INEGI's land use and vegetation cover data sets (Moreno-Sanchez *et al*. 2012). This study overcomes these shortcomings by making use of the most up-to-date INEGI land use and cover data sets to produce maps of the levels of fragmentation of the forests at national level in three dates (1993, 2003 and 2008).

## 3. Data sets

The most recent versions of the Land Use and Vegetation Cover vector data sets scale 1:250 000 known as Series II (from 1993), Series III (from 2002) and Series IV (from 2008) created by the INEGI were used in this study (Victoria-Hernandez *et al*. 2011). These data sets have been recently revised and their land cover and vegetation classes have been homogenized to facilitate comparisons across time. They were obtained from INEGI as ESRI's (Environmental Systems Research Institute, Redlands California) shape files in Lambert Conformal Conic datum NAD 83 units meters projection.

The original forest vegetation cover classes detailed in Appendix were extracted from the Series II, III and IV to create the more general temperate and tropical forest classes used in this study. Previous studies have used more disaggregated forest classes (Moreno-Sanchez *et al.* 2011 and 2012). However, as noticed in those studies, several of the more specific forest types (e.g. temperate broadleaf forest) are embedded in other forests (e.g. coniferous forests) and hence the edge and fragmentation effects are nonexistent in those cases. To achieve the goals of this study it was deemed sufficient to use the general temperate and tropical forest classes as defined in Appendix. The islands of the coast of Mexico were included as part of this study.

## 4. Methods

The moving window method developed by Riitters *et al*. (2000) was chosen to generate maps showing forest fragmentation classes. This method was chosen over other alternatives for several reasons. First, it generates maps showing fragmentation classes which forest managers and stakeholders can easily understand as well as relate the maps to their experiences in the field. Second, the principles and calculations used to assign a fragmentation class to each cell are conceptually intuitive and computationally simple. Third, the model is easily implemented through the ATtILA (http://epa.gov/esd/land-sci/attila/index.htm) extension for the Geographic Information System (GIS) ArcView 3.x (ESRI, Redlands CA). Other methods that were tested, but not used, included the GUIDOS Toolbox developed by the European Union FORESTMOD Joint Research Center (http://forest.jrc.ec.europa.eu/download/software/guidos/), and the CLEAR forest fragmentation analysis project from the University of Connecticut USA (http://clear.uconn.edu/projects/landscape/forestfrag/).

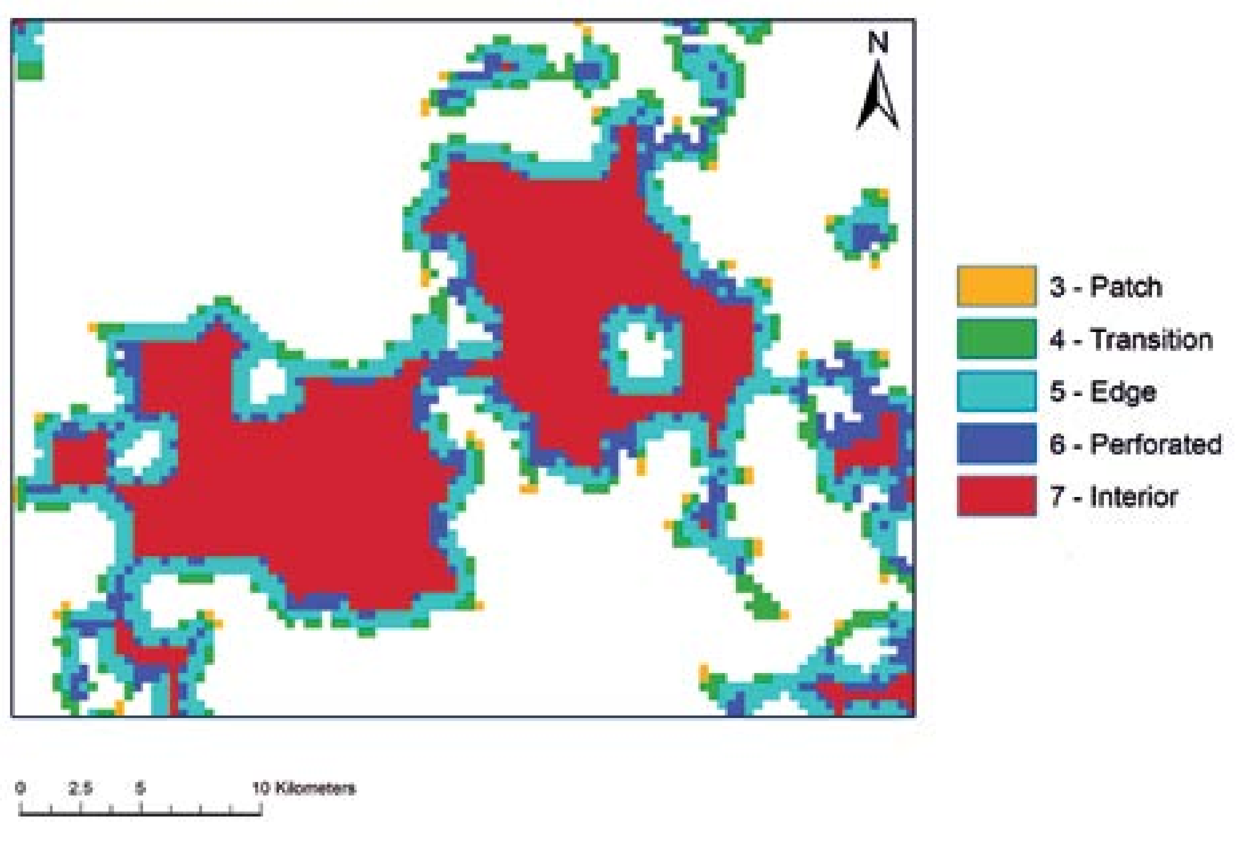
The Riitters *et al.* model (2000) belongs to a group of moving-window fragmentation indices (Kupfer 2006). The moving window defines a neighborhood that is analyzed to estimate the fragmentation value of the center cell in the window. Fragmentation classes are assigned to the center cell based on the proportion and adjacency of forested and non-forested cells in the analysis window (see Riitters *et al.* 2000 and 2002 for details). The fragmentation classes identified in increasing order of fragmentation are: Interior, Perforated, Edge, Transitional and Patch (see Figure 1).

The shapefiles defining the temperate and tropical forests were converted to ESRI's ArcGIS rasters with a cell size of 250 x 250 meters. An analysis window of 5 x 5 cells was then used to run the Ritters *et al.* (2000) methodology using the ATtILA software. These parameter values were selected based on experiences and results from previous studies (Moreno-Sanchez *et al.* 2012), and from tests performed during this study where different cell size and analysis window sizes were tested. It was determined that these parameter values are adequate to generate fragmentation classes that correspond to the levels of generalization and uncertainty associated with the vegetation classifications and scale of the original land cover data sets (1:250 000), as well as by the creation of the broad temperate and tropical forest classes defined in this study (see Appendix).

To provide easy and broad access to these cartographic results, without the need for locally

Figure 1

**illustrates the ArcGIS rasters showing the classes of forest fragmentation that resulted from the analyses. This type of cartographic results was generated for the temperate and tropical forests extracted from the Series II (1993), Series III (2003) and Series IV (2008).**




installed GIS software or high-end computing power, each cartographic result was exported to a Google Earth (GE) Super Overlay and saved in a compressed KML file (*.kmz) that was placed in a storage web service such as GoogleDrive or SkyDrive. End users can access these files over the Internet by downloading or opening them with computers that have GE locally installed. This enables users to take advantage of the context rich framework provided by GE with its high-resolution satellite images and ancillary information (e.g. roads, towns, local photos) to conduct their own visual analyses and dynamic exploration of the results at multiple scales. Each of the national level fragmentation maps were exported from ArcGIS 10.1 to a GeoTiff image with a resolution of 2400 dpi. These images were then used to create GE Super Overlays (https://support.google.com/earth/answer/176329?hl=en) using the software SuperOverlay (http://superoverlay.geoblogspot.com/). The KML compressed files (*.kmz) for each forest fragmentation map can be downloaded or open at https://sites.google.com/site/geoinfoforest-sofmexico/ using any computer with GE installed. Once one or more maps are loaded into the free version of GE (here version 7.1 was used), the maps can be turned on or off, and the transparency of each overlay can be changed on the GE left menu bar interface (see red circles in Figure 2) to compare against the GE images.

## 5. Results

Table 1 presents the results of the Riitters *et al.* (2000) fragmentation model applied to the temperate and tropical forests for INEGI's Series II, III and IV. This table shows: a) the area in hectares in each fragmentation category; b) the percentages of the total area of each forest type in each fragmentation category; and c) the percent change in areas within each fragmentation category from Series II (1993) to Series III (2003), from Series III to Series IV (2008), and to emphasize long term changes from Series II to Series IV.

In Table 1 it can be observed that for Series IV approximately 37% of the temperate forests and 34% of the tropical forests fall in fragmented categories (Edge, Transitional and Patch), while approximately

Table 1 Continue

**Areas in each fragmentation class for the temperate and tropical forests reported in INEGI's Series II, III, and IV**

**Temperate Forests**

| | Series IV | | Series III | | Series II | | % Change between | % Change between | % Change between |
|---|---|---|---|---|---|---|---|---|---|
| Fragmentation Class | Area (ha) | % of Total Area | Area (ha) | % of Total Area | Area (ha) | % of Total Area | Series II and III | Series III and IV | Series II and IV |
| Patch | 499 600 | 2.4 | 547 688 | 2.5 | 559 294 | 2.3 | 0.2 | -0.1 | 0.1 |
| Transitional | 2 119 893 | 10.0 | 1 997 556 | 9.0 | 2 107 556 | 8.5 | 0.5 | 1.0 | 1.5 |
| Edge | 5 228 119 | 24.6 | 5 336 169 | 24.1 | 5 790 088 | 23.4 | 0.7 | 0.5 | 1.2 |
| Perforated | 2 629 500 | 12.4 | 2 687 375 | 12.1 | 2 894 938 | 11.7 | 0.5 | 0.2 | 0.7 |
| Interior | 10 744 925 | 50.6 | 11 557 663 | 52.2 | 13 404 638 | 54.1 | -1.9 | -1.6 | -3.5 |
| **Total Area** | **21 222 038** | | **22 126 450** | | **24 756 513** | | **-10.6** | **-4.1** | **-14.3** |

**Tropical Forests**

| | Series IV | | Series III | | Series II | | % Change between | % Change between | % Change between |
|---|---|---|---|---|---|---|---|---|---|
| Fragmentation Class | Area (ha) | % of Total Area | Area (ha) | % of Total Area | Area (ha) | % of Total Area | Series II and III | Series III and IV | Series II and IV |
| Patch | 336 294 | 1.9 | 343 644 | 1.9 | 324 400 | 1.8 | 0.1 | 0.0 | 0.1 |
| Transitional | 1 568 955 | 8.7 | 1 429 075 | 7.9 | 1 397 194 | 7.6 | 0.3 | 0.8 | 1.2 |
| Edge | 4 212 519 | 23.5 | 4 333 063 | 24.0 | 4 269 700 | 23.1 | 0.9 | -0.5 | 0.4 |

Table 1 Concludes

**Areas in each fragmentation class for the temperate and tropical forests reported in INEGI's Series II, III, and IV**

Tropicale Forests

| | Series IV | | Series III | | Series II | | % Change between | % Change between | % Change between |
|---|---|---|---|---|---|---|---|---|---|
| Fragmentation Class | Area (ha) | % of Total Area | Area (ha) | % of Total Area | Area (ha) | % of Total | Series II and III | Series III and IV | Series II and IV |
| Perforated | 1 935 481 | 10.8 | 1 882 381 | 10.4 | 1 798 444 | 9.7 | 0.7 | 0.4 | 1.0 |
| Interior | 9 904 656 | 55.2 | 10 082 100 | 55.8 | 10 689 081 | 57.8 | -2.1 | -0.6 | -2.7 |
| **Total Area** | **17 957 906** | | **18 070 263** | | **18 478 819** | | **-2.2** | **-0.6** | **-2.8** |

50% and 55% fall in the Interior category respectively. Percent changes within each fragmentation category between dates considered and over the whole period studied (from series II to Series IV) are relatively small (see last column in Table 1). However, in both forest types there is a reduction of the Interior areas, with a larger reduction in the Temperate Forests (-3.5%) than in Tropical Forests (-2.7%). The last column also shows a larger decrease in total forest area in the Temperate Forests (-14.3%) than in the Tropical Forests one (-2.8%) during the period studied (1993-2008).

Table 2 shows the difference between areas that were reported as forests in Series II (1993) that are not reported as forests in Series IV (2008). A GE SuperOverlay of this difference in area for the temperate and tropical forests can be accessed at https://sites.google.com/site/geoinfoforestsofmexico/#TOC-Forest-cover-change-between-Series-II-1993-and-Series-IV-2008-. Table 2 also summarizes the forest area difference classified by fragmentation class corresponding to the fragmentation classification done for the forests in Series II.

Table 2

**Areas reported as forests in Series II but not reported in Series IV, classified by forest fragmentation class**

| Fragmentation Class | Temperate Forests | | Tropical Forests | |
|---|---|---|---|---|
| | Area (Ha) | % of Total Change | Area (Ha) | % of Total Change |
| Patch | 350 931 | 6.1 | 183 969 | 4.7 |
| Transitional | 1 052 750 | 18.2 | 653 831 | 16.5 |
| Edge | 1 723 825 | 29.8 | 1 238 650 | 31.3 |
| Perforated | 701 319 | 12.1 | 465 375 | 11.8 |
| Interior | 1 949 431 | 33.7 | 1 414 175 | 35.7 |
| **Total Change** | **5 778 256** | | **3 956 000** | |

These results were generated to explore the relation between forest cover change and fragmentation levels. It was decided to use the extremes of the time period available (Series II-1993 to Series IV-2008) in order to clearly see any trends. Of the forest areas that have disappeared between 1993 and 2008, approximately 34% were Interior areas in both temperate and tropical forests, followed by Edge areas (approximately 30% in both forest types) and Transition areas (approximately 17% in both forest types). More than half of the forest cover-loss falls in the fragmented categories (Edge, Transition and Patch) in the temperate (54%) and tropical forests (52.5%). It is interesting to notice that even though Interior areas constitute the largest percent of the forest cover (54% and 58% for the temperate and tropical forests in Series II respectively; see Table 1), and that areas classified as Edge constitute less than half that amount in the Series II (approximately 23% of the total forest area in both forest types), the percentage of loss in both categories appear as similar (approximately 34% and 30% respectively; see Table 2). These results suggest a clear association between higher levels of fragmentation and higher likelihood of those forest areas disappearing.

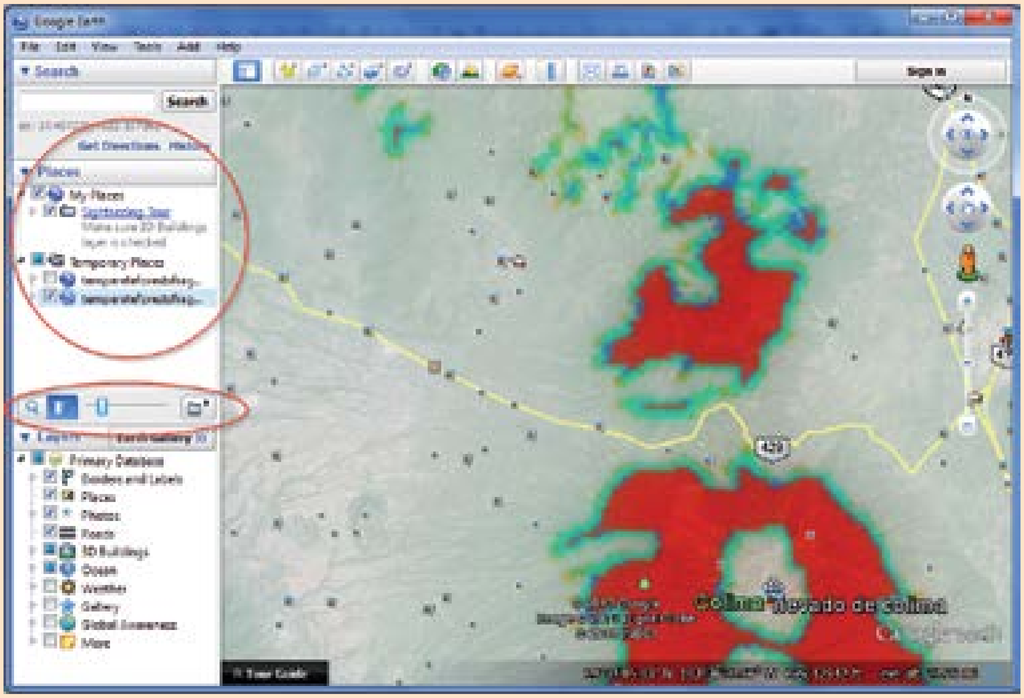
All the cartography resulting from this study can be found at https://sites.google.com/site/geoinfoforestsofmexico/. Figure 2 shows an example of the fragmentation levels of the temperate forests in Series IV in the area of the Nevado de Colima Volcano on the west coast of central Mexico. The red circles in the figure point to the locations in the GE (version 7.1) interface where overlays can be turned on and off and where the transparency of each overlay can be changed.

## 6. Discussion

The results of this study can support forest strategic level planning at national level (see Church

Figure 2

**Google Earth (version 7.1) interface showing forest fragmentation results for temperate forest in Series IV in the area of the *Nevado de Colima* volcano, close to the west coast of central Mexico. The GE controls for overlay transparency and turning on and off overlays are highlighted with red circles.**



*et al*. 2000 for discussion of forest strategic, tactical and operational level planning). For example, the results suggest that there is a relationship between high fragmentation levels and forest areas disappearance during the 1993-2008 period. The cartographic results of the forest extent and fragmentation levels for 1993, 2003 and 2008 can be explored to identify areas where significant changes in total forest cover and/or fragmentation have occurred. These areas can be targeted for implementation of conservation policies or forest education campaigns. In a different scenario, forests that have remained as Interior areas during the same period might be identified as hoping islands or corridors between major forest areas and hence can be highlighted for their conservation and ecological connectivity value. Muñoz-Piña *et al*. (2008) highlight the need to identify these types of areas in Mexico to better target compensations for forest ecosystem services.

The results of this study and the mechanisms used to distribute them can support forest and environmental education for diverse end users in Mexico and around the world. The use of the storage web services (e.g. GoogleDrive) to save the *.kmz files and GE to visualize them eliminates the need for local high-end computing expertise and software technology, and thus enables a broad audience of non-experts to have access to the information and carry out their own visual analyses. In contrast with traditional printed reports containing tables and small-scale maps, GE allows the dynamic exploration of the cartographic results at multiple scales in conjunction with the rich contextual information, recent-date satellite images, and spatial visualization features available through its interface.

It is important to point out that the visual analyses of the results against GE high-resolution images must be done realizing the limitations and proper use of the original data and results of this study. The original data was intended to create land use and vegetation cover maps with a scale of 1:250,000 at the national level. It was generated from Landsat images with 30 meter resolution. The original forest vegetation types in the Series II, III and IV were grouped in this study in more general temperate and tropical forest types. Hence, the end user must be aware of the generalization and classification impacts of these facts besides the errors of classification incurred when processing the satellite images used to create the Series II, III and IV. See Muller *et al*. (1995), Joao (1998), Mackaness and Chaudhry (2008) for generalization effects, and Corry and Lafortezza (2007) for discussion on issues when combining information that originated from sources with different scales or resolutions. Some of the discrepancies between the overlays produce in this study and the more recent-date and high-resolution GE images are due to actual land cover changes in the period since 1993, 2003 or 2008 and today. Others are due to classification errors and the generalization issues just mentioned. Despite these considerations, the visual comparison of GE images and the results of this study provide a clear indication of land cover changes that have occurred between the dates of the INEGI's Series and the present.

Our tests of GUIDOS (http://forest.jrc.ec.europa.eu/download/software/guidos/) and the CLEAR forest fragmentation project (http://clear.uconn.edu/projects/landscape/forestfrag/) to create maps of fragmentation levels of the forests were not satisfactory. We tested different cell sizes and values for the parameters required by each tool, but the resulting fragmentation maps provided little information. For example, most tests generated obvious results such as large areas classified as Interior with a band of one or two cells classified as Edge on the perimeter of the forest patches, with little or no representation of other fragmentation classes.

Finally, this study does not distinguish between natural and anthropogenic induced fragmentation. For some ecosystem functions or species this distinction does not matter. However, we recognize that knowing the causes of fragmentation in different places is essential for developing effective management, conservation, or restoration plans.

## 7. Conclusions and perspectives

According to INEGI's Series II, III and IV land cover data and the results of applying the Riitters *et al.* (2000) method, the fragmentation of temperate and tropical forests in Mexico has increased for each of the dates considered in the study. The forest cover of each forest type has decreased during the same period. Easily accessible dynamic digital maps that communicate the spatial relationships of the remaining forest patches to their spatial context are as important as numeric estimates of their extent and level of fragmentation.

Traditional reports containing numeric estimates and printed small-scale maps of the extent of remaining forest areas and rates of deforestation are not enough to communicate and assess the condition and trends of the remaining forests in Mexico. Because of its ecological importance and implications for sustainability, an assessment of the level of fragmentation of the remaining forest areas should be incorporated into forest national reports.

Besides statistics, forest national reports should also incorporate digital cartographic products that can be explored dynamically at multiple scales in a hardware/software platform that is easy to access and operate by a broad audience of end users from school children to forestry professionals. The combined use of GE and storage web services in the Internet is one of such platforms. Its low technological and know-how requirements, rich ancillary information and low cost make it an attractive option to distribute and visualize digital cartographic information. It is also a powerful communication tool that eloquently shows the spatial relations of the forest ecosystems with other natural and human-built environments. GE makes the information "personal" for diverse end users, and in doing so greatly contributes to their forest and environmental education and awareness. For example, school children can clearly see where forests previously existed and the spatial relation of their communities to deforested areas and land use changes. Forest and conservation managers can see the reduced areas that are truly "Interior" in their forests and plan accordingly.

Enabling end users to carry out their own exploration and visual analyses of the fragmentation results presented at different scales can assist in better designing and targeting strategic level forest management, conservation, restoration, and economic incentives efforts and policies at the national level. End users should be aware of the limitations and proper use of the results of this study as presented in the discussion section above. Regardless of these considerations, we argue that there is policy, planning, and educational benefits to our results and the way we propose to carry out their distribution and access by end users.

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# Appendix

Continues

**Vegetation types from INEGI's Series II, III and IV included in the definition of Temperate Forests and Tropical Forests**

| INEGI's CVE_UNION code | Description |
|---|---|
| **Temperate Forests** | |
| BA | *Bosque de oyamel* |
| BB | *Bosque de cedro* |
| BC | *Bosque cultivado* |
| BG | *Bosque de galería* |
| BI | *Bosque inducido* |
| BJ | *Bosque de tascate* |
| BM | *Bosque mesófilo de montaña* |
| BP | *Bosque de pino* |
| BPQ | *Bosque de pino-encino* |
| BQ | *Bosque de encino* |
| BQP | *Bosque de encino-pino* |

## Appendix

Concludes

**Vegetation types from INEGI's Series II, III and IV included in the definition of Temperate Forests and Tropical Forests**

| INEGI's CVE_UNION code | Description |
|---|---|
| BS | *Bosque de ayarín* |
| **Tropical Forests** | |
| SAP | *Selva alta perennifolia* |
| SAQ | *Selva alta subperennifolia* |
| SBC | *Selva baja caducifolia* |
| SBK | *Selva baja espinosa* |
| SBP | *Selva baja perennifolia* |
| SBQ | *Selva baja subperennifolia* |
| SBS | *Selva baja subcaducifolia* |
| SG | *Selva de galería* |
| SMC | *Selva mediana caducifolia* |
| SMP | *Selva mediana perennifolia* |
| SMQ | *Selva mediana subperennifolia* |
| SMS | *Selva mediana subcaducifolia* |
| VSA/PT | *Vegetación secundaria de selvas arbórea/vegetación de Petén* |
| VSA/SAP | *Vegetación secundaria de selvas arbórea/selva alta perennifolia* |
| VSA/SAQ | *Vegetación secundaria de selvas arbórea/selva alta subperennifolia* |
| VSA/SBK | *Vegetación secundaria de selvas arbórea/selva baja espinosa* |
| VSA/SBQ | *Vegetación secundaria de selvas arbórea/selva baja subperennifolia* |
| VSA/SG | *Vegetación secundaria de selvas arbórea/selva de galería* |
| VSA/SMQ | *Vegetación secundaria de selvas arbórea/selva mediana subperennifolia* |
| VSA/SMS | *Vegetación secundaria de selvas arbórea/selva mediana subcaducifolia* |
| VSA/BS | *Vegetación secundaria de selvas arbórea/bosque de ayarín* |