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Estrategias para la restauración forestal en comunidades del municipio de Motozintla, Chiapas, México

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Introducción

Los bosques de todo el mundo tienen una gran importancia socioambiental. Por una parte, mantienen el equilibrio ecológico a través de los servicios ecosistémicos que brindan (provisión de agua, conservación de la biodiversidad, fertilidad del suelo y regulación climática) y, por otro lado, suministran los principales bienes (leña, madera, fibras, medicinas, entre otros) necesarios para el desarrollo de las comunidades humanas y de otros organismos (Lamb y Gilmour 2003; Lamb et al. 2005; Rey-Benayas et al. 2009). En particular, los bosques de las regiones montañosas son reconocidos globalmente por su importancia social y ambiental (Körner y Ohsawa 2006).

El estado de Chiapas, localizado en la región tropical del sur de México, posee una de las biotas más ricas de México y América Central (Miranda 1952; González-Espinosa et al. 2005; Ramírez-Marcial et al. 2010). Se estima que el estado cuenta con una riqueza arbórea aproximada a 1,517 especies en 460 géneros de 105 familias botánicas (González-Espinosa et al. 2004; González-Espinosa y Ramírez-Marcial *en prensa*), lo que representa el capital natural necesario para el desarrollo de una creciente población humana en la entidad. Sin embargo, como resultado de la explotación forestal, ocasionada por la agricultura tradicional y el pastoreo extensivo, los bosques de Chiapas han sufrido una acelerada disminución en su cobertura arbórea, alterándose también su composición florística, estructura y función (de Jong et al. 1999; Ochoa-Gaona y González-Espinosa 2000; Ochoa-Gaona 2001; Ramírez-Marcial et al. 2001; Cayuela et al. 2006), lo que pone en riesgo el suministro de los bienes y servicios necesarios para la subsistencia de muchas comunidades, principalmente las indígenas y campesinas mestizas (González-Espinosa et al. 2007, 2008). Una de las regiones que ha sufrido la devastación más severa de sus bosques es la región Sierra Madre de Chiapas, una abrupta cadena montañosa que corre paralela a la línea costera del Océano Pacífico, desde el Istmo de Tehuantepec hasta el oeste de Guatemala (Richtier 2000; Cortina-Villar et al. 2012). De acuerdo a Waibel (1946), en dicha región la riqueza de recursos naturales estaba principalmente representada por bosques mixtos de pino-encino, bosques maduros de encino y bosques de niebla, en los cuales árboles de 20 a 40 m de altura eran los elementos dominantes de la vegetación. Sin embargo, en los últimos años el aprovechamiento forestal (clandestino y autorizado) condujo a una extrema deforestación; las 183,000 ha de bosque existentes en 1990 se redujeron a menos de 53,000 ha en 2005, lo que representa una disminución de la cobertura arbórea del 70% (Villafuerte 2010). Dado el actual nivel de degradación ambiental y debido a sus características de montaña, en la región se ha incrementado notablemente la vulnerabilidad a deslaves e inundaciones ante fenómenos hidrometeorológicos extremos (Richter 2000; Caballero et al 2006; Hernández-Moreno 2011), con lo que también se acentúa la fragilidad social y económica de las familias en las comunidades (Villafuerte y Mansilla 2010; Alvarez-Gordillo 2011), cuyos índices de pobreza y marginación están entre los más altos del país (CONEVAL 2010).

La restauración de la cobertura arbórea en la región Sierra Madre de Chiapas, no sólo es urgente para contrarrestar el deterioro ambiental, sino que resulta de vital importancia para mantener o restaurar la provisión de los servicios que brinda el bosque, así como de los bienes necesarios para la subsistencia de las comunidades de la región. No obstante las diversas necesidades de las comunidades en cuanto a recursos forestales, es común que los programas de restauración utilicen un reducido número de especies (a menudo monocultivos) teniendo como principal objetivo satisfacer las exigencias industriales (Carle y Holmgren 2008; FAO 2010), lo que frecuentemente resulta en fracaso para proporcionar a la gente medios de vida sostenibles y mantener la provisión de los servicios ecosistémicos. Por su parte, Rey-Benayas et al. (2009), así como González-Espinosa et al. (2011) argumentan que para lograr la viabilidad prolongada de cualquier programa de restauración forestal, tanto la elección de las áreas como la definición de la estrategia a implementar no sólo depende de la situación biofísica local, sino también de las condiciones sociales, económicas y culturales de los propietarios del bosque. Es aquí donde la participación de las comunidades locales en la discusión y adopción de decisiones, así como en la formación de alianzas y redes de colaboración con otros tomadores de decisiones, cobra una gran relevancia para el desarrollo de los programas de acción en un territorio con usos de bosque particulares (Cartagena-Ticona et al. 2005; González-Espinosa et al. 2007, 2008; German et al. 2010; Persha et al. 2011).

En el presente trabajo se considera que la restauración forestal en la Sierra Madre de Chiapas, o en cualquier otra región, además de atender los aspectos biofísicos del territorio debe partir de la más amplia consideración posible de las necesidades e intereses de la población local para luego incentivar su participación en la definición de las áreas a restaurar, las especies arbóreas a utilizar y por lo tanto, el diseño de la estrategia a implementar.

Con base en lo anterior se plantearon los siguientes objetivos:

Objetivo general

Analizar los medios de vida en cuatro comunidades de la región Sierra Madre de Chiapas con el fin de diseñar en conjunto con la población local estrategias para la restauración forestal que en el corto plazo atiendan sus necesidades e interés respecto al bosque, y que en el largo plazo ayuden a mantener los atributos biofísicos del área y la provisión de los servicios ecosistémicos.

Objetivos específicos

1. Evaluar los capitales con los que cuentan las familias de cada comunidad y determinar la estrategia de vida que de ellos se deriva.
2. Conocer el significado del bosque en las estrategias de vida de las familias y el interés que tienen respecto a la conservación y (o) recuperación de su superficie.
3. Acordar con las comunidades áreas potenciales y especies arbóreas a utilizar en programas de restauración forestal en terrenos de la comunidad.
4. Evaluar la condición arbórea y la fertilidad del suelo en las áreas acordadas para definir un plan local de restauración de las áreas boscosas.
5. Obtener un mapa comunitario de vulnerabilidad a deslaves e identificar áreas prioritarias para la restauración forestal.

Materiales y métodos

El área de estudio corresponde a la parte alta de la “Cuenca Hidrográfica Transfronteriza Grijalva” localizada en la porción sureste de la región Sierra Madre de Chiapas. Dentro de la cuenca se pueden localizar 67 comunidades, de las cuales fueron seleccionadas cuatro para el desarrollo del presente trabajo: El Carrizal (CA), Vicente Guerrero (VG), Benito Juárez (BJ) y Poblado Cambil (PC) (Figura 1). Para abordar los tres primeros objetivos se utilizó el marco conceptual de Medios de Vida Sostenibles. Se concibe como medios de vida a la combinación de recursos (capitales) que las familias de las comunidades poseen y a las actividades que realizan para vivir día a día y alcanzar sus propósitos a futuro. La habilidad para desarrollar diferentes actividades (que en conjunto conforman la estrategia de vida) depende de la disponibilidad y acceso a los diferentes capitales presentes en las comunidades (DFID 1999). Con base en Parra et al. (2009), se llevaron a cabo talleres comunitarios participativos con cinco grupos focales con los cuales se evalúo el acceso y calidad de los capitales presentes en las cuatro comunidades. La unidad de análisis fue la "familia típica" de cada comunidad y los capitales considerados fueron: (1) el natural que se refiere a la disponibilidad de los recursos naturales, (2) el financiero, que se refiere al nivel de ingreso y las fuentes de financiamiento con las que cuenta cada "familia típica", (3) el social, que se refiere a las organizaciones comunitarias y las redes de colaboración que operan para cada comunidad, (4) el humano, que se refiere a las habilidades, conocimientos y capacidades de trabajo que las personas poseen y, (5) el físico, referente a la infraestructura comunitaria, las herramientas y los servicios básicos que hay en los hogares. La "familia típica" se construye participativamente durante el desarrollo del taller y se refiere a la composición y número de integrantes que en promedio tienen las familias de cada comunidad. En CA la "familia típica" es de 8 personas (un abuelo, los padres y cinco hijos), en VG es de 9 (los padres y siete hijos), en BJ de 8 (los abuelos, los padres y cuatro hijos) y en PC de 6 (los padres y cuatro hijos). La información obtenida en los talleres se categorizó en cinco valores: uno para la peor condición y cinco para la mejor. Posteriormente, se estandarizó a 1.0 en el programa DEFINITE 2.0 para hacer las comparaciones intercomunitarias. El análisis de la información obtenida en los talleres permitió determinar la estrategia de vida que las familias han desarrollado así como los principales factores biofísicos, sociales, económicos y políticos que la han condicionado. Además, durante los talleres se pudo acordar con los miembros de la comunidad las áreas y las especies arbóreas a utilizar en posibles programas de restauración forestal. Dentro de las áreas acordadas se trazaron ocho parcelas circulares de 1000 m^2 (*sensu* Ramírez-Marcial et al. 2001) a fin de evaluar la estructura y composición arbórea. Para la estructura se midió el diámetro a la altura del pecho (DAP) y para la composición se contaron los individuos de las diferentes especies. En cada parcela se tomaron tres muestras de suelo a dos profundidades: 0-20 y de 21-40 cm, para evaluar su fertilidad y apoyar la definición de la estrategia de restauración mediante la recomendación de prácticas específicas dirigidas a superar las limitaciones de cada área. Las muestras de suelo se secaron y tamizaron antes de ser enviadas al laboratorio de suelos de ECOSUR en San Cristóbal de Las Casas, Chiapas, donde se determinó la densidad aparente, capacidad de campo, pH, materia orgánica, fósforo total y capacidad de intercambio catiónico. Mediante un análisis en Sistema de Información Geográfica (SIG) e información derivada de Hernández-Moreno (2011) se incorporaron datos sobre cobertura arbórea, tipo de roca, distancia a caminos y ángulo de la pendiente en un modelo espacial para identificar las áreas de mayor vulnerabilidad a deslaves y así identificar áreas prioritarias para la restauración forestal, comparando su correspondencia con las áreas acordadas con la población de las cuatro comunidades estudiadas.

Title: Rural livelihoods and their implication for forest restoration strategies: a case from Chiapas, Mexico.

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Abstract:
Forest ecosystems provide the required natural capital to maintain rural livelihoods in mountain regions. However, inadequate land-use and forest utilization practices put at risk the provision of goods and services and increase landslide vulnerability. A successful long-term forest restoration strategy should start from considering the needs and interests of people in a bottom-up participatory strategy with a locally tailored program. We analyzed rural livelihoods within four communities of the Sierra Madre region of Chiapas, Mexico, to design along with them a forest restoration strategy that in the short-term could satisfy their interests and needs with regard to forest products; in the long-term, the strategy is aimed to restore biophysical conditions that could protect the watershed. We draw upon forest inventories and evaluation of soil fertility to define a local restoration strategy with practices tailored to overcome plot-level limitations. The results indicate that families within the study region live under high natural, economic and social vulnerability. Families are strongly dependent on aid programs; 45-68% of the annual income of an average family comes from subsidies. Unfortunately, most of these subsidies do not contribute to support a sustainable livelihood. Community firewood supply was an issue that allowed convening on the definition of specific tree species and areas to be assigned to forest restoration plans. A strategy for forest restoration would have to be considered as an element within a larger package of land-use options directed to watershed protection, as well as to support the provision of firewood, timber, and agricultural products to local families. Current policies support conflicting practices that hamper forest restoration as a viable and useful land-use option. Yet they could be aligned to support sustainable rural livelihoods based on a diversified resource use to enhance adaptation of local populations to regional and global changing conditions.

Keywords: communal resources, family capitals, landslide vulnerability, montane cloud forest, public policies.

Introduction

Almost one fifth of the world population (1.2 billion inhabitants; Körner and Ohsawa 2006) lives in montane areas and depend directly on forests resources to maintain their rural livelihoods (Soini 2005; Körner and Ohsawa 2006; SCBD 2009; Toillier et al 2011). Yet inadequate land-use practices and unsustainable forest use have provoked high deforestation rates in recent decades (Achard et al 2002; Curran et al 2004; Cayuela et al 2006). Steep slopes and shallow soils interact with forest clearing and degradation in upper montane regions to increase landslide and flood risks for populations in the face of extreme hydrometeorological events (Hewitt 1992; CIFOR 2005; Bradshaw et al 2007). In turn, soil erosion results in decreased agricultural productivity and compromises food security and the overall well-being of rural communities that habit and depend directly on this ecosystem (Biggelaar et al 2003).

Livelihoods are defined as a combination of resources (capitals) and activities that families within a community put in operation on a daily basis to attain their long-term purposes (DFID 1999). In montane areas maintenance of forest cover may be intricately linked to rural livelihoods and in many areas excessive deforestation compromises the provision of timber, firewood, other non-timber products, and ecosystem services not only for local communities but for other human groups in lower parts of the watershed as well (Körner and Ohsawa 2006; Luck et al 2009). In such areas, restoration of forest cover is not only urgently needed to mitigate environmental degradation, but it becomes vital to maintain or restore ecosystem goods and services that support the livelihoods of rural communities (Lamb and Gilmour 2003; Lamb et al 2005; Rey-Benayas et al 2009; SCBD 2009). It is not uncommon that montane communities live in marginal conditions that have favored their adaptation through a diversified use of natural resources (Jodha 2000; Toillier et al 2011). It is noteworthy the strong dependence that rural communities have on sources of firewood and charcoal (Brown 1980; Martin et al 2011). Yet it is also not uncommon that forest restoration programs focus on using low-diversity tree plantations (often monoculture) aimed to meet industrial needs in the first place (Carle and Holmgren 2008; FAO 2010). These projects frequently do not consider the basic needs and interests of local people, with the ensuing effect of not being adopted for the support of sustainable livelihoods and the provision of some ecosystem services like climate regulation, soil fertility and biodiversity. Rural people in developing countries maintain a number of needs, interests, and traditions on their forest resources that have to be considered in the definition of forest restoration programs. Direct participation of the local communities in the decision stages and in forming alliances and collaborative actions, based on mutual confidence with other stakeholders are essential to attain the long-term adoption of forest restoration programs (Jodha 2000; Scherr 2000; González-Espinosa et al 2007, 2008; SCBD 2009; German et al 2010; Persha et al 2011).

The state of Chiapas is located in the southernmost area of Mexico, bordering with Guatemala, includes both the richest biotas in Mexico and Central America (Miranda 1952; González-Espinosa et al 2005; Ramírez-Marcial et al 2010) and some of the most marginalized rural populations in the country (CONEVAL 2010). The tree species richness of Chiapas includes at least 1517 species in 460 genera and 105 botanical families (González-Espinosa et al 2004; González-Espinosa and Ramírez-Marcial in press). However, land-use patterns aimed to agricultural and livestock production have provoked a severe loss of forest cover and degradation of floristic richness, forest structure and possibly impairment in the provision of ecosystem goods and services like firewood, timber, water infiltration, soil fertility and microclimate regulation (de Jong et al 1999; Ochoa-Gaona and González-Espinosa 2000; Ochoa-Gaona 2001; Ramírez-Marcial et al 2001; Cayuela et al 2006).

The Sierra Madre region of Chiapas, an abrupt mountainous chain that runs parallel to the Pacific Ocean coastal line, from the Isthmus of Tehuantepec into western Guatemala, is one of the most severely devastated regions in Mexico and Guatemala (Richter 2000; Cortina-Villar et al 2012). From the time of the first large wave of colonization of the region in the mid-1920´s, Waibel (1946) reported that the most important natural resources in this region included several different forest ecosystems (pine-oak mixed forests, old-growth oak forests, and tropical montane cloud forests) that were heavily logged for timber and converted to others land-uses. A high deforestation, mostly due to illegal logging, continued until recently: forest cover decreased from 183000 ha in 1990 to less than 53000 ha in 2005 (70% reduction; Villafuerte 2010). Extensive land-use change from forest to agricultural open areas that need the input of agrochemicals, and the occurrence of very steep slopes have increased socioeconomical vulnerability in high areas of the region, and landslide and flood risk for population in lower areas (Richter 2000; Caballero et al 2006; Villafuerte and Mansilla 2010; Hernández-Moreno 2011).

A successful long-term forest restoration program should start from a full consideration of the needs and interests of people in a bottom-up participatory strategy in which they decide the line of action of a locally tailored program (González-Espinosa et al. 2011). Yet forest recovery may conflict with agricultural and livestock activities and the policies that promote them. In this study we use the analysis of rural livelihoods within four communities in the Sierra Madre region of Chiapas, Mexico, in order to design along with them a forest restoration strategy that in the short-term satisfy the interests and needs of local people in regarding to forest products, and in the long-term help to maintain at watershed-level biophysical conditions required for the provision of ecosystem services. The Sustainable Livelihoods Framework was used to diagnose community capitals, at the same time offering an opportunity to convene with local people on areas and tree species to be restored. We draw upon forest inventories and evaluation of soil fertility to define a local restoration strategy with practices tailored to overcome plot-level limitations. Landslide vulnerability and priority areas for forest restoration were identified with GIS (Geographic Information System) analysis based on forest cover, bedrock type, distance to roads, and slope angle to obtain a community-level map. This study provides an analysis of factors and processes that determine community development in montane regions, as well as an insight on the local interaction of biophysical and socioeconomical variables relevant for long-term forest restoration programs.

Methods

Study area

The study was conducted in four communities within a watershed with a complex mixture of metamorphic and sedimentary rocks from the Mesozoic and igneous rocks from the Cenozoic (Waibel 1946; Müllerried 1957; Carfantan 1997), in the municipalities of Motozintla de Mendoza (Motozintla for short) and Mazapa de Madero (Mazapa for short), in the Sierra Madre region of Chiapas (Figure 1). The area within the watershed is 120 km^2 and encompasses a steep elevation gradient from 420 up to 2850 m, with mean annual temperature of 24 and 14° C, respectively. Rainfall in the rainy season (May-October) is 900 mm in the lower sites, but may exceed 3000 mm at higher elevations; rainfall during the dry season (November-April) ranges 75-700 mm in low and high areas, respectively (INEGI 1985). Soils in the region include acrisols, cambisols, regosols, and andosols (INEGI 1988). Original vegetation included tropical dry forest and pine-oak forest at lower elevations, and pine, pine-oak and montane cloud forests in higher areas (Waibel 1946; Breedlove 1981). Most of the forest cover has been removed or severely degraded and replaced by agricultural fields (rainfed cultivation of maize and beans) and fallows on steep slopes. The study region was incorporated to the Mexican territory in 1882 after being part of Guatemala (Villafuerte and García 2004). Yet the municipalities of Motozintla and Mazapa were more heavily colonized from the early 20th century onwards, when they became sources of seasonal work force for the coffee *fincas* owned by German colonists in Guatemala and the neighboring Soconusco region facing the Pacific Ocean (Richter 2000; Villafuerte and García 2004; Villafuerte and Mansilla 2010). Land was given to these workers in order to secure them within the *fincas*.

For this study four communities were chosen among a total of 67 settlements within the watershed. They were selected because of their contrasting environmental conditions and the willingness of local people to collaborate with the project: (1) El Carrizal (CA from here onwards), 15°24ˈ9" N, 92°17ˈ50" W, 2180 m elevation, 578 inhabitants; (2) Vicente Guerrero (VG from here onwards), 15°22ˈ56" N, 92°18ˈ38" W, 2165 m elevation, 407 inhabitants; (3) Benito Juárez (BJ from here onwards),15°21'57" N, 92°18'45" W, 2060 m elevation, 766 inhabitants; and (4) Poblado Cambil (PC from here onwards), 15°23ˈ10" N, 92°10ˈ6" W, 1333 m elevation, 169 inhabitants (INEGI 2010). It should be noted that population in the four communities has not increased over the last 10 years, most probably due to increasing emigration of young people that leave the family household to cities where employment opportunities may exist (Villafuerte and Garcia 2004). Yet, the population of whole municipalities has increased during the same period 10% and 15% respectively (INEGI 2010, Villafuerte 2010).

Rural livelihoods

The Sustainable Livelihoods Framework (DFID 1999) was used to assess the activities conducted by families over the last decades as well as the public policies aimed to support the development in the four studied communities. Following Parra et al (2009), we conducted community-level participatory workshops with focal groups to assess different community capitals, with a hypothetically constructed household (typical family) as the unit for analysis. Five capitals were considered: (1) natural capital or availability and access to natural resources, (2) financial capital which refers to financial sources available to households, (3) social capital or collaborative relationships existing within each community, (4) human capital which refers to abilities, knowledge and working capacities that people possess, and (5) physical capital or available community infrastructure, and tools and basic services in households. Categories 1-5 (worst to best) were defined on emerging qualitative variables that were subsequently standardized (to one) in the DEFINITE 2.0 software to obtain intercommunity comparisons. The analysis also allowed to assess the interest of the whole community with regard to forest recovery actions, and in particular the potential of degraded forest sites and tree species to be involved in future forest restoration projects.

Forest structure

Floristic composition, structure, and soil characteristics were assessed in degraded forest stands identified by local inhabitants for restoration plans. In each site we set eight 1000 m^2 circular plots (17.8 m radius) to obtain basal area of trees >20 cm diameter to breast height (DBH); basal area of trees 10.1-20.0 cm DBH were obtained within a concentric 500 m^2 circle, and of individuals 5.1-10 cm DBH within a central 100 m^2 circle. Two subplots (1 × 2 m) were set inside the 100 m^2 circle and individuals >15 cm height and with DBH <5 cm were counted (Ramírez-Marcial et al 2001). Voucher specimens were collected and used to identify unknown species in the herbarium at El Colegio de la Frontera Sur (ECOSUR) in San Cristóbal de Las Casas, Chiapas. All tree species were included in a portable catalog for field identification.

Soil fertility

Three composite soil samples (from five subsamples on a pentagon 3 m at each side) were collected inside each 1000 m^2 circular plot from two soil layers at 0-20 cm and 20-40 cm depth (3 samples in each plot × 8 plots × 4 communities × 2 soil layers = 192 samples). The samples were air-dried and sieved in a common garden before being sent to the laboratory to determine apparent density, water retention at field capacity (membrane method), pH, organic matter (OM, Walkley-Black method), total phosphorus (P, Olsen method), and cationic exchange capacity (CEC, ammonia method). All laboratory analyses were performed at the Soils Laboratory of ECOSUR at San Cristóbal de Las Casas, Chiapas. Differences among the studied communities (localities) were evaluated with a nested analysis of variance with community as fixed factor and plots as a random nested factor within communities. Analyses were performed with the SPSS v. 15 statistical package. A decision tree was constructed with soil variables using categorical values in the Official Mexican Norm *NOM-021-RECNAT-2000* (SEMARNAT 2002) as follows: pH (<6.5, 6.5-7.3, >7.3), OM (<6.1%, 6.1-10.9%), CEC (<15.1 mg kg^{-1}, 15.1-25.0 mg kg^{-1}, >25.0 mg kg^{-1}) and P (<5.6 Cmol kg^{-1}, 5.6-11.0 Cmol kg^{-1}, >11.0 Cmol kg^{-1}).

Assessment of landslide vulnerability

Following Hernandez-Moreno (2011) with some modifications, we designed and used a spatial model to determine landslide vulnerability within the four studied communities based in four variables: forest cover, bedrock type (lithology), distance to roads, and slope (from here onwards our proposed FOLDS model). Each parameter was rated according to the probability of landslide occurrence based on field observation, literature review and expert's opinions (see details in Supplemental data, Appendix S1). A combination of ArcView 3.2 geoprocessing tools, ArcGIS 9.2 and Quantum GIS tools, including Model Builder extension, were used to process spatial data and to assign vulnerability ratings. As a result, we generated the vulnerability maps that show areas with higher qualifications where landslides are most expected, and lower values where landslides are less likely to occur. This procedure allowed us to determine an arithmetic mean for each pixel, which was then reinterpreted through a four category FOLDS vulnerability index of likeliness of landslides to take event: 1 = low, 2 = medium, 3 = high and 4 = very high. The resulting maps allowed identify forest restoration priority areas and their relation with potential areas suggested by local people. The equation for the FOLDS index is:

$$FOLDS_{index} = \frac{F_r + L_r + D_r + S_r}{4}$$

where:

F = forest cover; *B* = bedrock type (lithology); *D* = distance to roads; *S* = slope angle.
r = rating given to each parameter based on likeliness of a landslide to occur.

Results

Rural livelihoods

In all the studied communities the cumulative assessments of capitals were very low (0.39 – 0.55), indicative of heavy marginalized conditions in all households and very limited productive options at the community level. In all cases, the lowest values were recorded on social capital (0.18-0.28), which is indicative of lack of community organization to address limitations impinging on the other capitals (Figure 2). The observed precariousness of the five community capitals assessed relates to the widespread practice of rain-fed agriculture without soil conservation practices but with high level requirement of agrochemicals which decreases or almost nullifies any profit margin of product sold in local markets (Table 1). All the studied communities have been the target of a number of federal and state-sponsored programs, including subsidies aimed to support mostly food security, health, education and productive activities, and environmental protection to a lesser extent. In all cases subsidies are directed to provide short-term assistance on basic needs rather than supporting long-term sustainable productive activities (Table 2). Typical family cash income includes 45-68% received through government subsidies (about 50% of annual income), while productive activities and paid work only provide 23-36% and 7-21% of the total, respectively. Yet cash income in the studied communities is quite below (36-88%) the nationally accepted threshold set for food poverty (Figure 3).

Forest restoration

In all communities people identified (on locally made maps) those lands to be assigned to forest restoration as those under current communal use for firewood and timber extraction: *Astilleros* (ruled by the *ejido* authority), communal school plots (under supervision of the parents committee) and communal pasture lands (only at PC). (*Ejido* refers to land granted to communities where they grow crops and use natural resources based on community agreements; *ejido* families live within designated areas for their households, while other pieces of land are assigned for individual cultivation or communal use; González-Espinosa et al 2011). In addition, local people showed an interest in implementing forest recovery along river margins and in areas where landslides had occurred in the recent past. The number and identity of tree species preferred for firewood and timber varied among communities: El Carrizal (7 species), Vicente Guerrero (10 spp.), Benito Juárez (6 spp.), and Poblado Cambil (7 spp.). The most used tree species for firewood were *Diphysa americana*, *Quercus castanea*, *Q. laurina*, *Q. peduncularis*, *Q. segoviensis*, and *Q. vicentensis*, and *Pinus* spp. and *Cedrela salvadorensis* for timber. Other less frequently used species for either firewood or timber were *Acacia pennatula*, *Arbutus xalapensis*, *Bursera bipinnata*, *Carpinus caroliniana*, *Lysiloma divaricatum*, *Quercus candicans*, and *Q. crassifolia*. In all studied communities the adult density of the preferred tree species was negligible, with the possible exception of *Quercus peduncularis* at Poblado Cambil (Figure 4). Natural regeneration potential of preferred tree species varied widely among the four studied communities. Only in the communities of Poblado Cambil and Vicente Guerrerro a few species (4 and 2, respectively) had a mean number of more than one seedling within an area of 10 m^2. Negligible densities of seedlings, saplings and adults were recorded for all preferred tree species in the communities of El Carrizal and Benito Juárez (Figure 4). People in all communities insisted on the establishment and management of a local nursery to propagate local species that might of interest to them.

Soil fertility

All variables examined in the 0-20 and 20-40 cm deep soil layers were significantly different ($P < 0.049$) among the four studied communities, except apparent density in the deepest layer (*P* = 0.075) (Table 3, Figure 5). The soil layer was not included as a factor in the analysis as only the superficial layer (0-20 cm deep) was considered as an indicator of site potential for restoration practices within the first years of the process. The 20-40 cm soil layer was sampled to provide a baseline for future assessments of the effects of restoration practices and no further results will be presented in this paper. Superficial soils in 23 out of 32 plots had moderately acid soils (pH < 6.5), seven plots had neutral values and two showed alkaline values (Figure 6). Fertility of the studied soils was low or medium in most plots: one half of them had low OM values, only seven plots showed high CEC levels, and one third of the plots had high P values (Figure 6).

Landslide vulnerability

In all communities the areas with high and very high landslide vulnerability coincided with cleared lands (crop fields and fallows) that were close to roads (both paved and dirt), and were located at less than 100 m and on steep slopes (> 50%). Forested areas away from roads were associated with medium and low vulnerability risks, irrespective of their slope angles. In CA, VG and BJ granitic bedrock was associated to lower vulnerability risks (Figure 7; see details Supplemental data, Appendix S2 and S3). It is noteworthy that most human settlements are in areas with high and very high vulnerability to landslides.

Discussion

Landslide vulnerability mapping

Landslide vulnerability mapping can be a guiding tool for forest active restoration, especially where key information is lacking or incomplete. The applied FOLDS model used input data from different spatial scales, from very detailed SPOT images to nationwide geological surveys with a 1:250000 scale. Heterogeneity of data input can be a result of this difference of scales as well as some variables being more heterogeneous *per se*. Instead of resulting in an absolute vulnerability value, our proposed model is useful in identifying a relative vulnerability among areas within the communities. We propose the FOLDS model as a quick assessment methodology that could be used in local scenarios sharing some attributes with our study area, to determine priority areas for active restoration based on biophysical data and processing of satellite imagery which can be integrated with local concerns, needs and interests. Yet a further validation and calibration should be conducted in order to determine model accuracy. We find information on landslide vulnerability as a useful tool for planning at the local level; however landslides and their possible effects can only be visualized partially with this approach. Other elements that can be added to a wider analysis are threats by extreme hydrometeorological events, social preparedness and (or) organizational, technical or cultural constraints, as well as infrastructure resistance. We suggest however using the output as one accompanying a wider set of information to address the problem in an integrated approach.

Livelihoods and public policies

Rural people inhabiting mountain areas have adapted to their environment through the development of strategies that maintain their livelihoods and subsistence (Jodha 2000). The prevailing idea that this people living in remote and marginal areas (Körner and Ohsawa 2006) has prompted actions from the public sector to help overcome their poverty and isolation, yet necessarily with due consideration of their livelihoods and environmental implications at local level.

Social development policies implemented by the Mexican government have been under continuous transformation (Székely 2002); yet they still consider subsidies as the basic tool to help rural communities (León 2011). As it is observed in the study area, public policies have been mostly focused on providing infrastructure and basic services like health care and education, in addition to economic incentives to individual families that may represent up to 68% of their annual income in cash. This large amount may not represent a problem by itself, but the way in which it does not support a local sustainable development. There are a number of consequences derived from the application of public policies through cash incentives that may lead to perverse relationships between communities and the state within the study area. First, subsidies have become a major element of family income, livelihoods and social reproduction strategies in mountain regions of Chiapas (Villafuerte 2010), not implying that they are effective or aligned to promote sustainable development. Secondly, it is observed that subsidies aimed to provide food security through the products of rain-fed agriculture on steep slopes have not only failed in their main goals, but have worsened natural capital when converting forests into open areas exposed to severe soil erosion and increased landslide risks. Scheer (2000) proposes that implementation of misguided and non-aligned public policies aimed to support community development may be the key driver of environmental degradation rather than the activities of poor families by themselves. The increase of forest areas within the watershed through restoration plans in non-communal areas seems now problematic because of the strong dependence of individual families on subsidies to maintain maize cultivation and to buy cereals in local markets. Thirdly, local awareness on increasing landslide vulnerability and risks derived from forest clearing is at odds with the need to accept the subsidies for rain-fed agriculture (Álvarez-Gordillo 2011). Finally, we observed that a long-term consequence of the aid programs in the study area, as León (2011) reports from other areas of Mexico, is that growth of human capital and community empowerment have been severely hampered, debilitating social networks and community involvement in public policy implementation (Cartagena-Ticona et al 2005). Therefore, external public policies dictate development goals and natural resource management at both local and regional scales (Morán et al 1998). One way that Melick et al (2007), Persha et al (2011) and German et al (2010) have evidenced as a mean to avoid social and ecological negative effects in forest management and conservation plans is the involvement of local people in forest use rule making. We add to this the need to strengthen all community capitals through capacity building and promoting community institutions that can define and guide forest restoration plans aimed to the long-term provision of a wide number of environmental goods and services.

Potential and limitations of forest restoration

A close interaction between our academic group and local people developed as a result of the livelihood workshops held in each studied community. Firewood supply was the emerging issue that brought together community members on the definition of specific tree species and areas to be assigned to forest restoration plans. As a first attempt at forest restoration, local people decided that activities should involve only communal areas that already provide firewood to community members, as well as areas where landslides had occurred recently. However, as it can be seen in Figure 7, areas selected by the community for restoration projects mostly do not coincide with the high priority ones based on their landslide vulnerability. Passive forest restoration in the study area is impeded, and clearly is a non-viable strategy, due to community dependence on firewood, making a case of decreasing ecosystem resilience due to (chronic) human impact (Lamb and Gilmour 2003; Folke te al 2004). In addition, widespread low soil fertility in the areas selected by those communities to conduct restoration plans indicates the need to include practices to overcome it (addition of litter, use of fertilizer, terracing for soil conservation, and so on). Restrepo (2009) reports that passive forest recovery in areas where landslide has occurred is dependent on the availability of nutrients and propagules. In most of the studied areas we found scant natural regeneration, suggesting, instead, the need for an active forest restoration strategy with the participation of local people is required to either initiate the recovery process or to accelerate the rate at which it proceeds (Lamb and Gilmour 2003).

Firewood use is recognized as a major public health problem in rural communities of developing countries (Martin et al 2011). Yet, in the short term these communities cannot substantially reduce their firewood use to meet their household energy needs. Although a number of technologies could be brought about in order to help reduce firewood demand (more efficient cookstoves, solar heating devices), it seems that in the short term the sustainable supply of firewood must be linked to forest recovery. Interest in establishing a community nursery to propagate those tree species that are highly valued as a source of firewood has been a crucial step in the development of a locally tailored forest restoration strategy.

Nationwide current policies centered on payment for ecosystem services (PES), as promoted by the *Comisión Nacional Forestal* (CONAFOR), typically lack a social basis as they do not consider the needs and interests of local people and mostly focus on financing the preservation of forested areas (Cortina-Villar et al 2012). The results of this study indicate that in the short-term attention should be given not only to developing forest cover but also to the reconversion of current argicultural fields into more intensive production units that use less land and more local labor force (González-Espinosa et al in press). In the end, an increase in forest extent beyond those communally used areas would have long-term benefits for watershed protection, and could be aligned with the current and mid-term needs for firewood, timber and cash income by local families.

Conclusions

Families within the study region live under high vulnerability conditions and their natural, social and financial capitals are in an ongoing process of increasing degradation. A strategy for forest restoration would have to be considered as an element within a larger package of land-use options directed to watershed protection as well as support provision of firewood, timber, and agricultural products to local families. Current public policies support conflicting practices that hamper forest restoration as a viable and useful land-use option. Yet they could be aligned in order to support sustainable rural livelihoods based on a diversified resource use to enhance adaptation of local populations to regional and global changing conditions.

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Figures

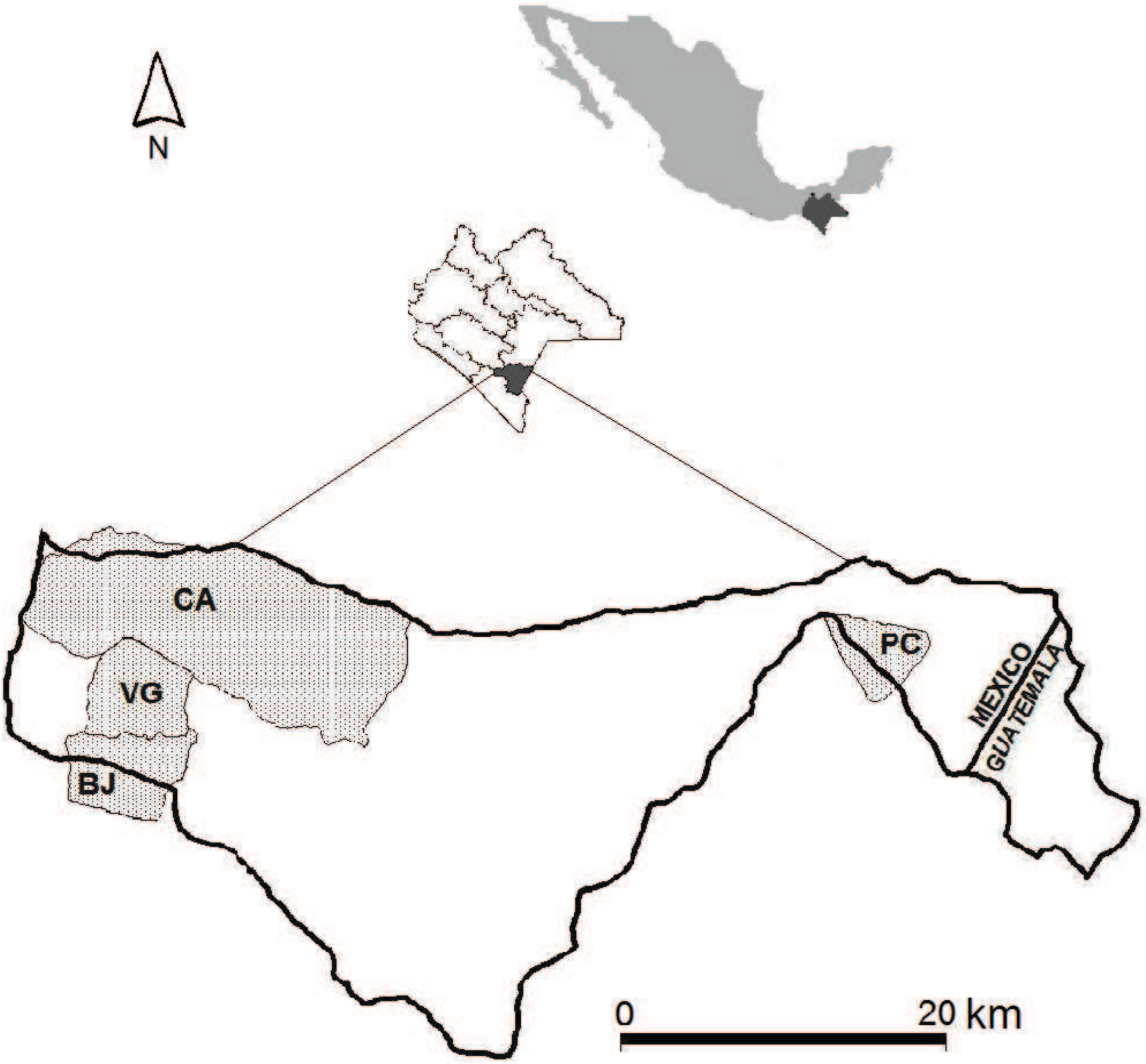


Figure 1. Location of Chiapas and the southernmost Sierra Madre region (dark grey). Location of the four communities studied within the watershed (heavy black line): CA = El Carrizal; VG = Vicente Guerrero; BJ = Benito Juarez; PC = Poblado Cambil.

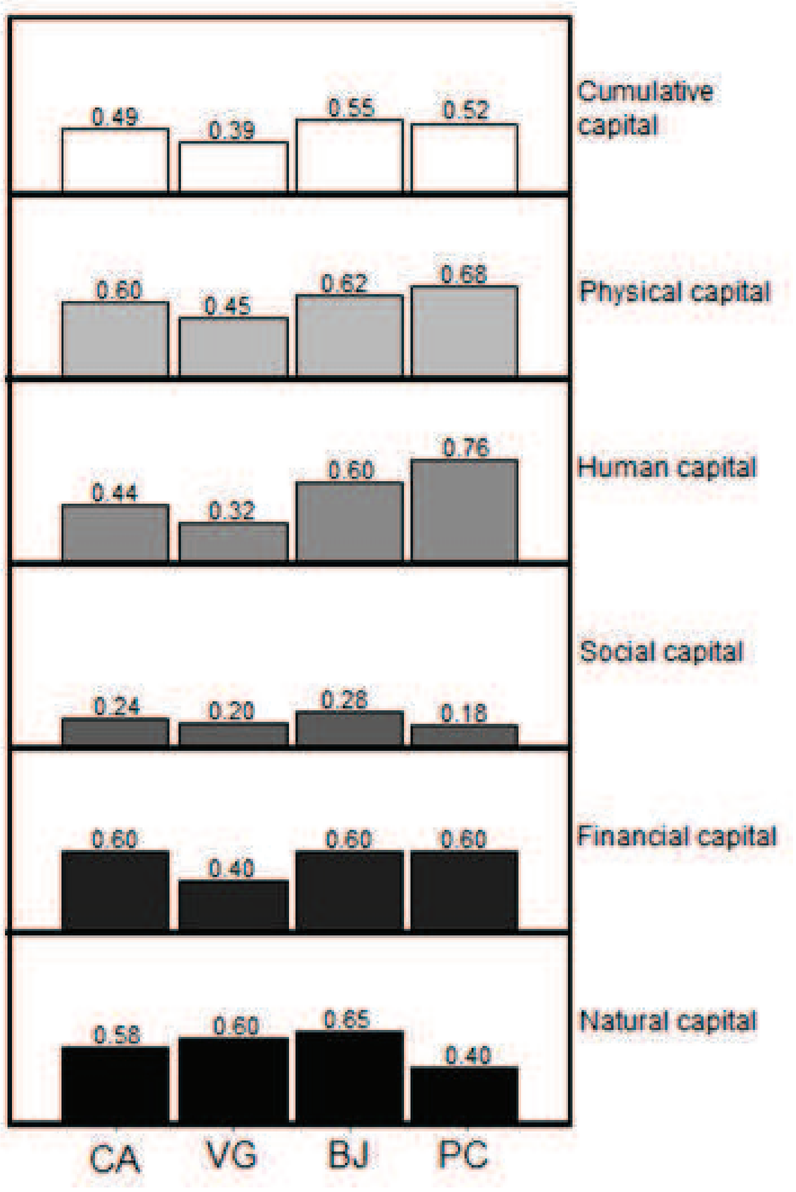


Figure 2. Capitals assessed through the livelihoods workshops conducted in each community. Values were obtained with the DEFINITE 2.0 software (Institute for Environmental Studies, Vrije Universiteit Amsterdam) through standardization (0-1.0) of categorical values (1.0-5.0) given to each capital. Community acronyms as in Fig. 1.

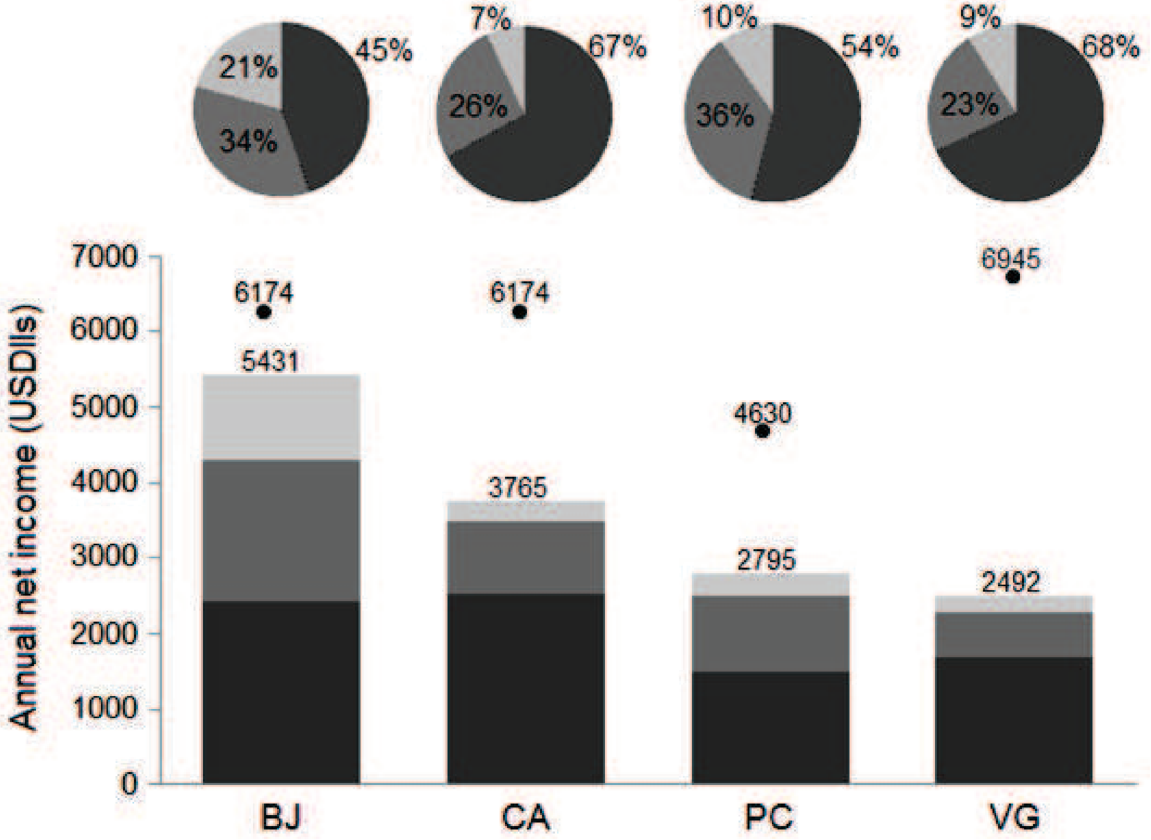


Figure 3. Sources of annual net income of “typical families” in each community and their comparison with the corresponding *Línea de pobreza alimentaria* (Food poverty threshold) established for Mexico by the *Consejo Nacional de Evaluación de la Política de Desarrollo Social* (CONEVAL), based on $771.72 USDlls. per person in a “typical” rural family. (Light grey = paid work, medium grey = productive activities, dark grey = government subsides, dark point = food poverty threshold) Original data were obtained through the livelihoods workshops in each community. The exchange rate of Mexican *peso* to USDlls. used is $12.75 MX = 1.0 USDll. on April 1, 2012. Community acronyms as in Fig. 1.

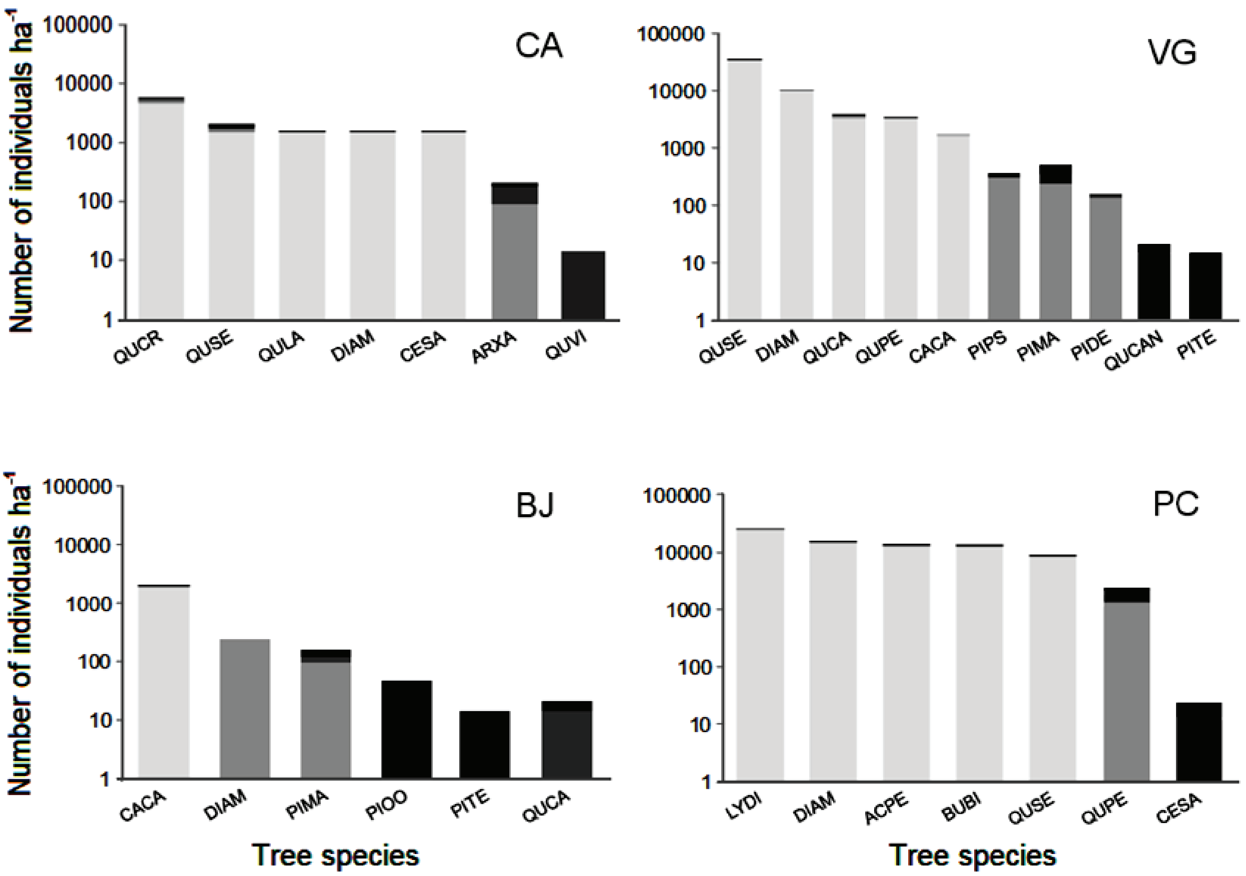


Figure 4. Density of seedlings (light gey), saplings (medium grey), small adults (dark grey) and large adults (black) of tree species within forested areas selected for restoration in each community. Only shown are those tree species on which people indicated a keen interest due to the provision of firewood and timber. QUCR = *Quercus crassifolia*; QUSE = *Quercus segoviensis*; QULA = *Quercus laurina;* DIAM = *Diphysa americana*; CESA = *Cedrela salvadorensis*; ARXA = *Arbutus xalapensis*; QUVI = *Quercus vicentensis*; QUCA = *Quercus castanea*; QUPE = *Quercus peduncularis*; CACA = *Carpinus caroliniana*; PIPS = *Pinus pseudostrobus*; PIMA = *Pinus maximinoi*; PIDE= *Pinus devoniana*; QUCAN = *Quercus candicans*; PITE = *Pinus tecunumanii*; PIOO = *Pinus oocarpa*; LYDI = *Lysiloma divaricatum*; ACPE = *Acacia pennatula*; BUBI; *Bursera bipinnata.*

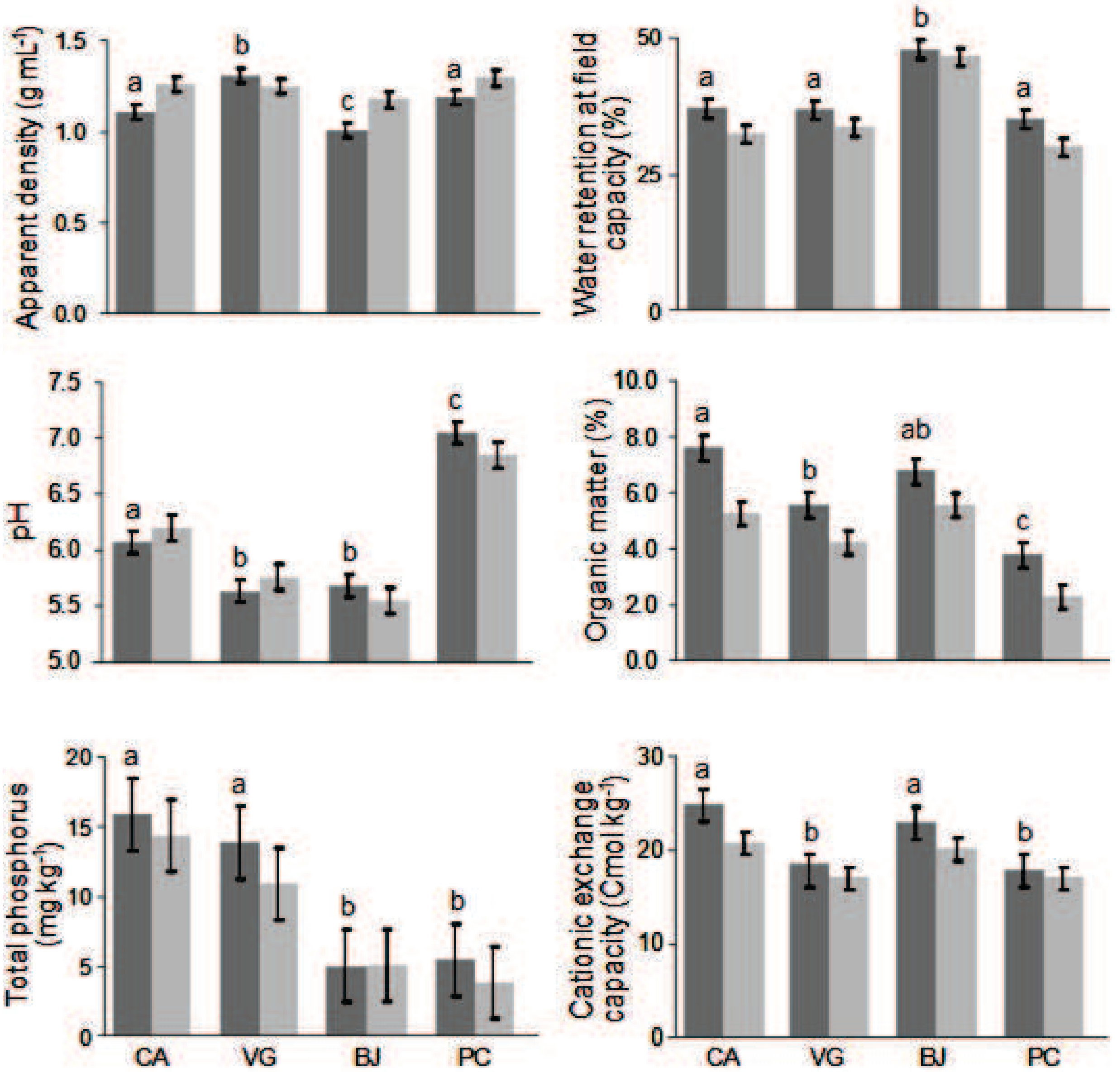


Figure 5. Mean values (± 1 SEM) of physical and chemical soil variables in two soil layers (0-20 cm depth, dark grey, and 20-40 cm depth, light grey) in forest stands selected for restoration in each community. Bars with the same letter above are not significantly different with ($P \leq 0.05$). Community acronyms as in Fig. 1.

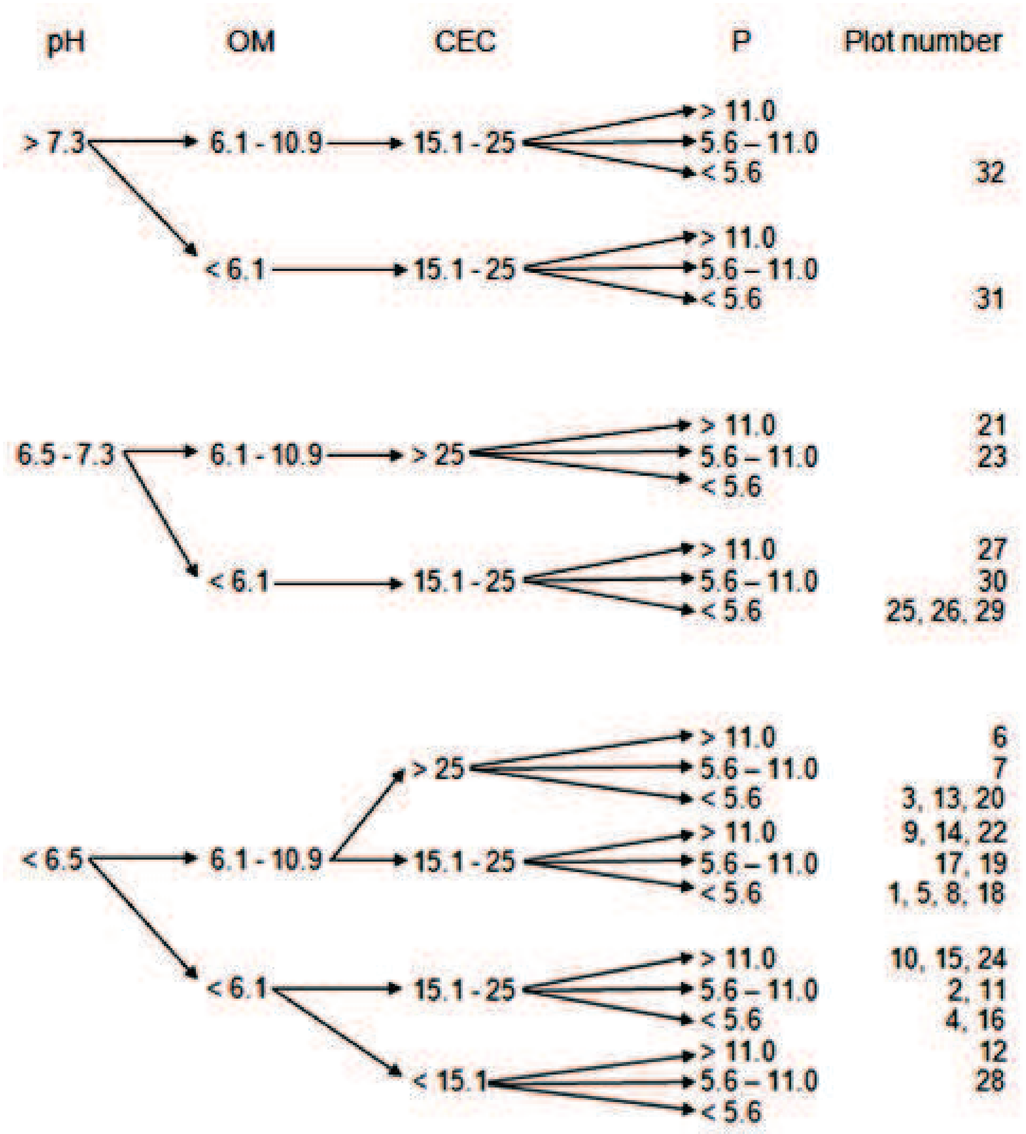


Figure 6. Decision tree constructed with soil variables using categorical values in the Official Mexican Norm *NOM-021-RECNAT-2000.* Plots in each community: CA = 17 to 24; VG = 9-16; BJ = 1-8, PC = 25-32. Community acronyms as in Fig. 1.

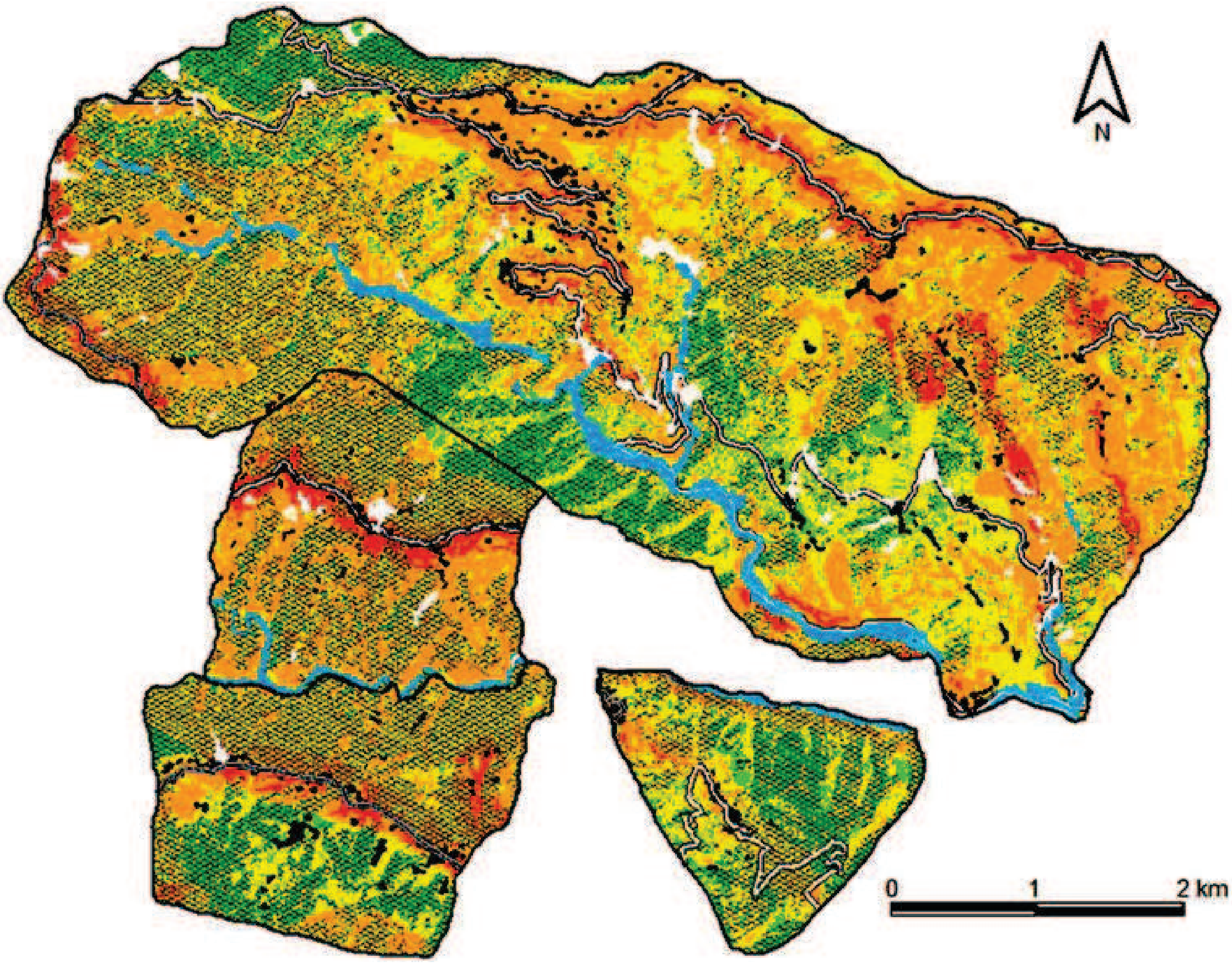


Figure 7. Landslide vulnerability classes in the four studied communities. Green = low, yellow = medium, orange = high, red = very high. Black lines indicate limits of each community lands. Also indicated are roads (both paved and dirt), human settlements (black areas), permanent rivers (blue), extent of landslides areas that could be identified in a 2011 satellite image (white areas), and areas where restoration activities would be acceptable by the communities (shaded areas). See further details in Supplemental data, Appendix S1.

Tables

Table 1. Maize and bean yield and market prices (within parenthesis), land surface used by each "typical family" to produce each crop (ha), number of members in a "typical family", subsistence indicators and agrochemicals used within a given year. Market prices were calculated for maize and beans as \$0.39 USDlls/kg and \$1.65 USDlls/kg, respectively, based on their prices at the Mexican Government official DICONSA stores. According to Körner and Ohsawa (2006) rural mountain people whose annual cereal production is < 200 kg per capita may be considered as vulnerable to food security. Community acronyms as in Fig. 1.

	CA		VG		BJ		PC	
	Maize	Bean	Maize	Bean	Maize	Bean	Maize	Bean
Yield (kg ha^{-1}) and price (USDlls ha^{-1})	1500 (\$585)	Variable	500 (\$195)	Variable	667 (\$260)	781 (\$1289)	1500 (\$585)	3125 (\$5156)
Crop land per family (ha)	2.0	Variable	1.0	Variable	1.5	0.32	1.0	0.08
Members in "typical family"	8: 1 elder, 2 parents and 5 children		9: 2 parents and 7 children		8: 2 elders, 2 parents and 4 children.		6: 2 parents and 4 children	
Amount (kg) and price (USDlls) of grain actually available for subsistence of each family	2000 (\$780)	All	500 (\$195)	All	1000 (\$390)	250 (\$413)	1000 (\$390)	250 (\$413)
Amount (kg) and price (USDlls) of grain actually available to be sold in local markets	1000 (\$390)	None	None	None	None	None	500 (\$195)	None
Amount (kg) and market price (USDlls) of grain bought to fulfill family subsistence needs	-----	-----	500 (\$195)	20 (\$33)	-----	-----	-----	-----
Agrochemicals used and their price (USDlls ha^{-1})	Urea-herbicide (\$204)		Ammonium sulfate-Gramoxone (\$474)		Urea/ammonium sulfate-Gramoxone (\$218)		Urea/ammonium sulfate-Gramoxone (\$167)	

Table 2. Federal (F) and state (S) public policies and programs aimed to support family development in the communities. SEDESOL = *Secretaria de Desarrollo Social*; DIF = *Sistema Nacional para el Desarrollo Integral de la Familia*; SECAM = *Secretaria del Campo*; SAGARPA = *Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*; CONAFOR = *Comisión Nacional Forestal*. ES=Elementary school, SS=Secondary school. Benefits are given in USDlls.

Program name	Ministry/ organization	Issues covered	Target beneficiaries	Annual amount (benefits)
Oportunidades	SEDESOL (F)	Nutrition Health Education	Housewife & children	Housewife: $381.18 1 child: $98.80 1 child (ES): $211.76 1 child (SS): $470.60
70 y más	SEDESOL (F)	Nutrition Health	Elders (> 70 yr old)	1 elder: $470.60
Amanecer	Gobierno de Chiapas (S)	Nutrition Health	Elders (> 64 yr old)	1 elder: $517.65
Desayunos escolares	DIF (F)	Nutrition	Pre-school and elementary level children	School breakfast
Piso Firme	SEDESOL (F)	Household improvement	Families	Concrete house floors
Estufas Ahorradoras de Leña	SEDESOL (F)	Household improvement/ Environment	Housewives	Kitchen stoves
Reconversión Productiva	SECAM (S)	Agriculture	Peasants	Productive inputs, cash money and training
Procampo	SAGARPA (F)	Maize cultivation	Peasants	$101.96 ha^{-1}
Maíz solidario	SECAM (S)	Maize cultivation	Peasants	$76.86 per peasant; seeds, fertilizer and herbicide
Pro-Árbol	CONAFOR (F)	Forestry/ Environment	Forest land owners with 5.0-100 ha each.	$118.51 ha^{-1} 1100 tree pine seedlings per hectare and $118.51 ha^{-1}

Table 3. Nested variance analysis of physical and chemical soil variables in two soil layers (1 = 0-20 cm depth, 2 = 20-40 cm depth) in the four studied communities. SV = source of variation, d.g. = degrees of freedom, SS = sum of squares, C= Community, C (P) = plot within community.

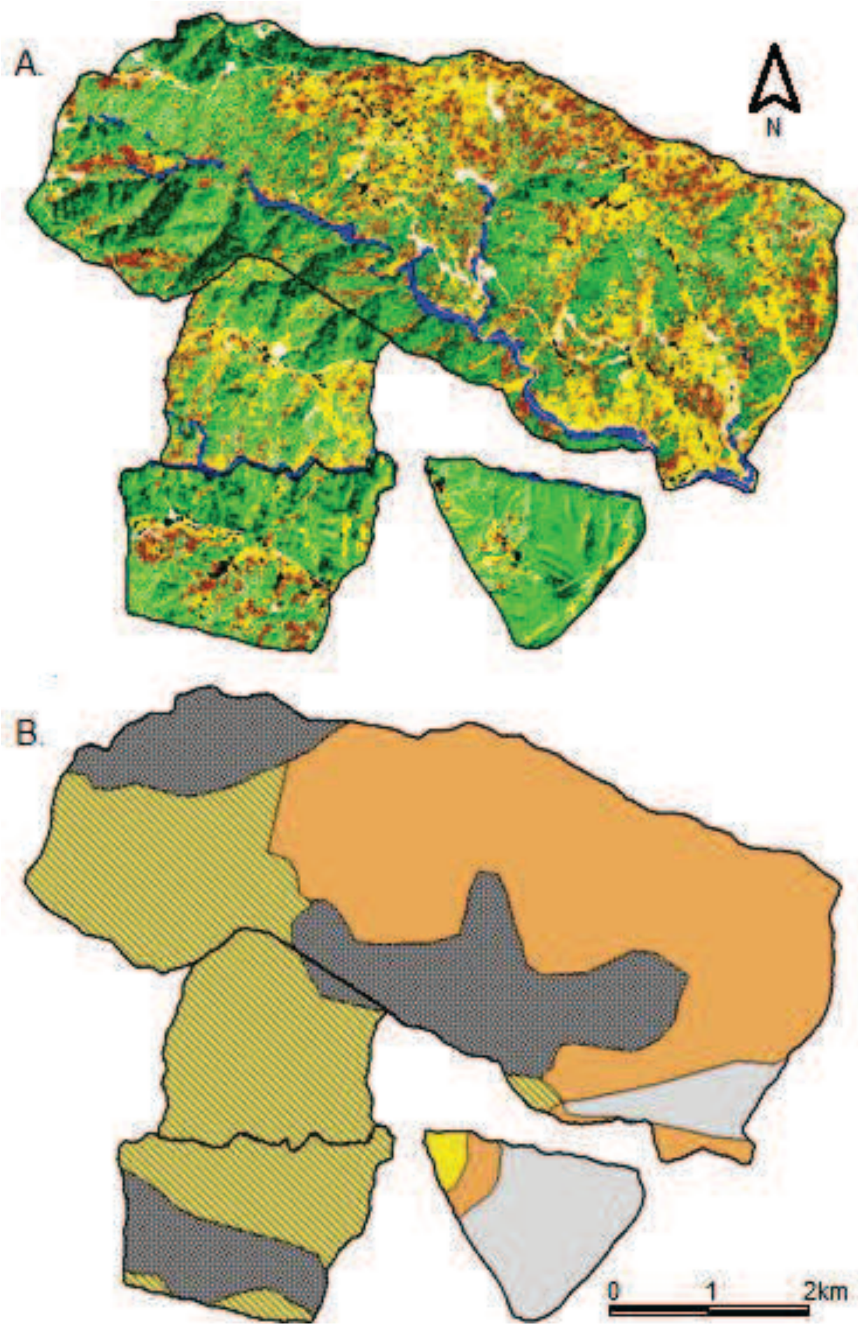
SV	d.g.	SS	*F*	*P*
Apparent density				
C-1	3, 28	1.14	10.96	<0.001
C(P)-1	28, 64	0.97	3.86	<0.001
C-2	3, 28	0.19	2.56	0.075
C(P)-2	28, 64	0.68	2.35	0.003
Water retention at field capacity				
C-1	3, 28	2437.28	13.38	<0.001
C(P)-1	28, 64	1700.27	3.40	<0.001
C-2	3, 28	3941.76	23.85	<0.001
C(P)-2	28, 64	1542.43	3.49	<0.001
pH				
C-1	3, 28	31.15	21.87	<0.001
C(P)-1	28, 64	13.30	7.9	<0.001
C-2	3, 28	23.88	13.94	<0.001
C(P)-2	28, 64	16	7.11	<0.001
Organic matter				
C-1	3, 28	199.18	5.86	0.003
C(P)-1	28, 64	317.28	9.28	<0.001
C-2	3, 28	158.14	4.95	0.007
C(P)-2	28, 64	298.18	9.78	<0.001
Total phosphorus				
C-1	3, 28	2258.81	3.01	0.047
C(P)-1	28, 64	6999.70	6.21	<0.001
C-2	3, 28	1768.05	3.18	0.039
C(P)-2	28, 64	5194.59	4.66	<0.001
Cationic exchange capacity				
C-1	3, 28	819.72	9.46	<0.001
C(P)-1	28, 64	808.46	1.58	0.066
C-2	3, 28	283.79	2.97	0.049
C(P)-2	28, 64	890.86	3.57	<0.001

Supplemental material

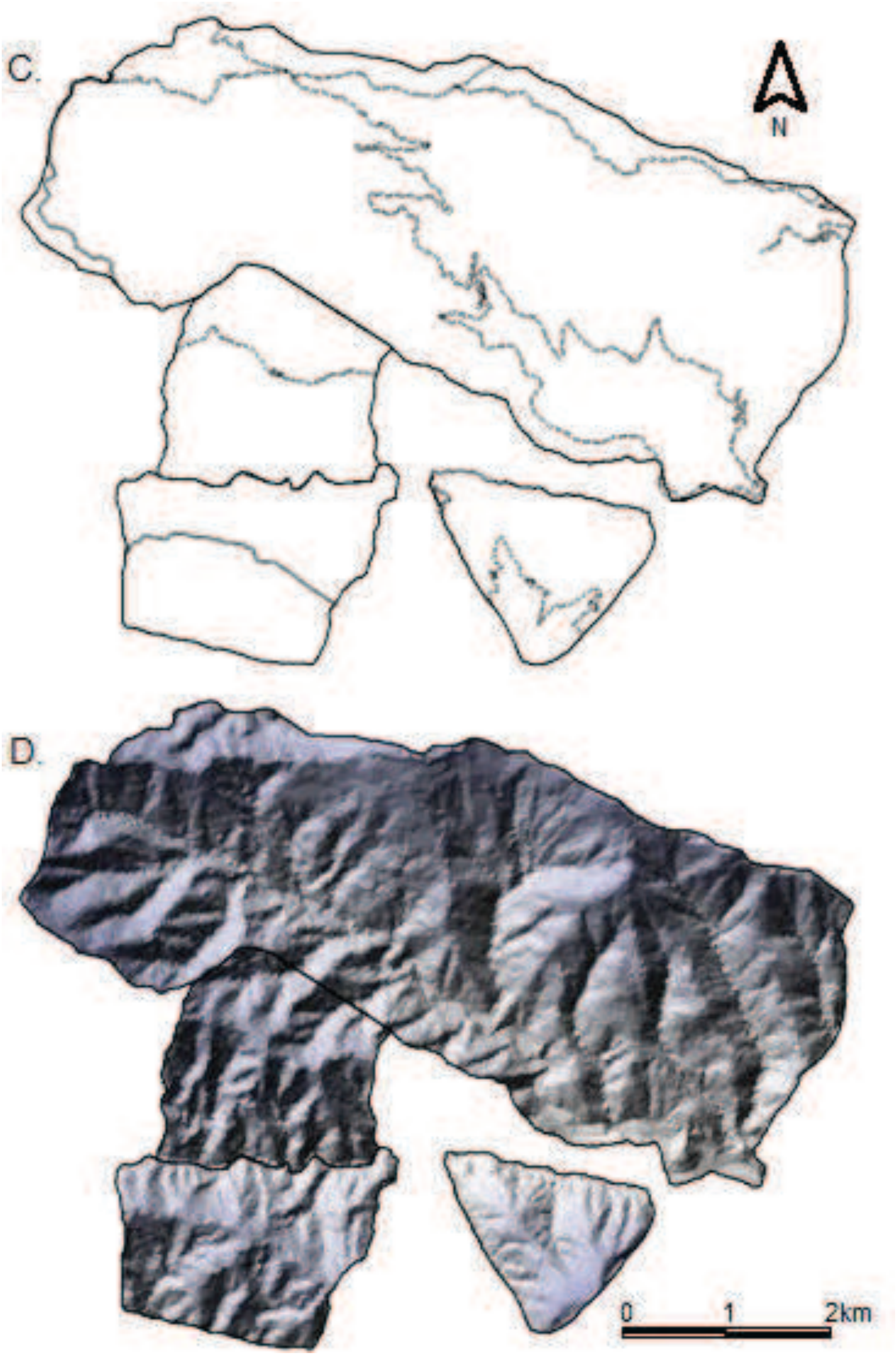
Appendix S1. Parameters and ratings used in landslide risk determination through the FOLDS model in the selection of priority restoration areas. Rating values means are: 1 = Low, 2 = Medium, 3 = High and 4 = Very high.

Parameter	Source of data	Data processing	Condition	Rating (r)
Current forest cover (FO)	SPOT image for 2011.	Merge resolution in ERDAS was applied to panchromatic and multispectral images with 2.5 and 10 m cell size. ArcView 3.2 was used to identify different types of forest and land cover. Conditions were classified following Ochoa-Gaona and Gonzalez-Espinosa (2000) with some modifications. Ratings were assigned based on the current landslide events and literature review.	Dense forest	1
			Disturbed forest	1
			Tree-dominated fallow	2
			Human settlements	3
			Crop fields	4
			Fallow fields	4
			Rivers	4
Bedrock type (L)	Carfantan (1997) INEGI (1988) Geological map, Scale 1: 250,000	Lithology was classified directly into vulnerability ratings based on literature review (Hernández-Moreno 2011).	Igneous rocks (granite)	1
			Metamorphic complex	2
			Alluvial soils and fine-grained sedimentary rocks (limolites).	3
			Medium-grained metamorphic rocks (schists).	4
Distance to roads (m) (D)	INEGI (2001) Topographic map Scale 1: 50,000	Buffer rings were determined at a distance of 50 m from paved and dirt roads. Buffer areas were reclassified into vulnerability ratings.	>151	1
			101 – 150	2
			51 – 100	3
			0 – 50	4
Slope (%) (S)	INEGI (2001) Topographic map, Scale 1: 50,000	Contour lines and elevation sources were combined to build a Triangulated Irregular Network (TIN) and a Digital Elevation Model (DEM). Slope was then calculated using standard spatial analysis tools available in Arc GiS 9.2. Values were reclassified into four equal interval vulnerability categories.	0 – 25	1
			26 – 50	2
			51 – 75	3
			> 75	4

Appendix S2. A. Types of forest and land cover in each studied community. Dark green = dense forest; medium green = disturbed forest; light green = tree-dominated fallow; yellow = crop fields; brown = fallow fields; blue = rivers; black = human settlements; white = areas without vegetation (landslides areas and roads). B. Bedrock type in each studied community. Dark grey = granite; yellow with diagonal lines = schists; orange = limolites; grey = metamorphic complex; yellow = alluvial soils. See community localization in Figure 1.



Appendix S3. C. Roads (paved and dirt) and D. Slope angle in Triangulated Irregular Network (TIN) in each studied community. See community localization in Figure 1.



Resultados y discusión

Medios de Vida

1. Las familias de las cuatro comunidades estudiadas poseen capitales muy limitados (Figura 2), lo que revela graves condiciones de marginación en todos los hogares, así como restringidas opciones productivas a nivel comunitario.

2. Las familias desarrollan una estrategia de infrasubsistencia ya que los rendimientos de la principal actividad productiva que realizan, agricultura de temporal intensiva con alto uso de agroquímicos (maíz-frijol), apenas alcanzan para cubrir el autoabasto dejándolas sin posibilidad de vender excedentes y generar recursos que apoyen su ingreso familiar (Tabla 1).

3. Las familias dependen para su subsistencia de los subsidios que el gobierno otorga en apoyo a la alimentación, salud, educación, producción y ambiente (Tabla 2). Anualmente estos subsidios comprenden hasta el 68% del ingreso familiar. Sin embargo, ni con ello pueden mejorar su nivel de vida que está por debajo del umbral de pobreza alimentaria (Figura 3). Al respecto, Villafuerte (2010) sugiere que los subsidios han pasado a formar parte de los medios de vida de la población serrana e incluso se han convertido en el modelo de reproducción social en la región. No obstante, ello no implica que los subsidios sean eficaces o estén alineados con las condiciones socioambientales para promover el desarrollo sostenible a un nivel local.

4. Los programas de gobierno, con su carácter meramente asistencialista parecen más obstaculizar el crecimiento y fortalecimiento del capital humano, así como el empoderamiento de las comunidades, que apoyar su desarrollo, tal como se ha señalado que ocurre en otras de México (León 2011). De acuerdo con Cartagena-

Ticona et al. (2005) esta dependencia debilita las redes de colaboración comunitarias, así como la participación de la población en la toma de decisiones para el desarrollo de políticas públicas de acción local.

5. Los subsidios dirigidos a apoyar el desarrollo agrícola en áreas de pronunciadas pendientes no sólo han fracasado en su objetivo de brindar a las familias seguridad alimentaria, sino que han agravado el deterioro del capital natural al promover la conversión del bosques a áreas abiertas para agricultura sin prácticas de conservación del suelo. Como resultado, las actividades productivas exponen las áreas abiertas a una mayor erosión y aumentan el riesgo de deslaves ante lluvias extremas. Scheer (2000) propone que la aplicación de políticas públicas equivocadas y mal alineadas dirigidas a apoyar el desarrollo de las comunidades puede ser el factor clave que conduce la degradación ambiental en lugar de las propias actividades que realizan las familias.

Potencialidades y limitaciones de la restauración

1. Los talleres de medios de vida realizados en cada comunidad tuvieron como uno de sus principales resultados la oportunidad de mantener una estrecha interacción y colaboración entre nuestro grupo académico y la población local.

2. La necesidad de mantener el abasto de leña (principal combustible de uso doméstico en las comunidades) fue el recurso emergente que permitió acordar con la gente las áreas y especies a utilizar en programas de restauración forestal.

3. Las áreas seleccionadas por la población local fueron aquellas de uso comunal: “astilleros” (áreas comunales para el abasto de leña), parcelas escolares y potrero (este último sólo en Poblado Cambil), así como aquellas áreas donde recientemente han

ocurrido deslaves. Sin embargo, como puede verse en la figura 7, las áreas seleccionadas por la comunidad en poco coinciden con las áreas prioritarias para la restauración con base en el análisis de su vulnerabilidad a deslaves.

4. El número y las especies de árboles preferidos varío entre las comunidades´. E El Carrizal se mencionaron siete especies, en Vicente Guerrero 10, en Benito Juárez seis spp. y en Poblado Cambil siete spp. Las especies arbóreas más utilizadas para leña fueron *Diphysa americana*, *Quercus castanea*, *Q. laurina*, *Q. peduncularis*, *Q. segoviensis* y *Q. vicentensis.* Otras especies menos utilizadas, ya sea para leña o madera fueron *Acacia pennatula*, *Arbutus xalapensis*, *Bursera bipinnata*, *Carpinus caroliniana*, *Lysiloma divaricatum*, *Quercus candicans* y *Q. crassifolia*.

5. El potencial de regeneración natural de las especies preferidas varíó entre las cuatro comunidades. Sin embargo, en la mayoría de las áreas evaluadas se registró escasa regeneración natural (Figura 4), además de baja fertilidad del suelo (Tabla 3, figuras 5 y 6), lo que sugiere la necesidad de implementar una estrategia de restauración forestal activa con la participación de la población local para iniciar o acelerar el proceso de recuperación de las áreas degradadas. El interés que la población mostró para el establecimiento y manejo de un vivero comunitario es un paso muy importante en el desarrollo e implementación de una estrategia de restauración de este tipo. Además, brinda la posibilidad de que el programa de restauración tenga una mayor aceptación por la población local así como una viabilidad prolongada.

Conclusión

Las familias en la región de estudio viven en condiciones de alta pobreza, marginación, inseguridad alimentaria y alta vulnerabilidad; sus capitales natural, humano, social y financiero están en un continuo proceso de deterioro. Una estrategia para la restauración del bosque tendría que ser considerada como un elemento dentro de un paquete más amplio de opciones de uso del suelo y dirigida a apoyar la protección de la cuenca, así como a mantener la provisión de leña, madera y productos agrícolas para las familias de las comunidades. Sin embargo, las actuales políticas que apoyan las actividades productivas resultan contradictorias y dificultan la restauración de los bosques como una alternativa viable y útil para el uso sustentable de la tierra. La posibilidad de alinear políticas para el desarrollo regional que incluyan la restauración de los bosques requiere de una comprensión de las condiciones sociales, económicas y ambientales en colaboración con las comunidades para apoyar sus medios de vida basados en un uso diversificado de recursos naturales a fin de contribuir a la adaptación de las poblaciones ante las cambiantes condiciones regionales y mundiales.