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Original Article

Changing mountain farmscapes: vulnerability and migration drivers in the Paute River watershed, Southern Ecuador

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Abstract: Abrupt changes in land use/land cover have often characterized Andean rural landscapes. This is particularly notorious in the Paute River watershed in southern Ecuador. We seek to show how, under tenets of the global economy, rural mountain landscapes suffer constant modifications due to the agricultural practices of dwellers and migrants. Erosion of arable slopes takes center stage in analyzing vulnerability due to the high erodibility factor found in this watershed. By using remote sensing and GIS applications, we analyzed the potential erodibility with intersections of rural development constraining of ecosystem services, including the production of water, food, and cultural values in the Paute River watershed. We found six sources of migratory flows and analyzed topographic and elevation effects in potential erodibility indexes of agroecological options to ameliorate the environmental stress. We identified factors associated with migration trends observed in the area and assessed vulnerability issues of resource management that could prevent deforestation, soil erosion, and acculturation amidst the pressures of development in the region. We conclude that sustainable development options can be implemented with a watershed management approach oriented to diminish emigration. This approach shall be integrative, inclusive, and respectful of the rich biocultural diversity heritage conservation of southern Ecuador.

Keywords: Farmscapes; Erodibility; Migration; Rurality; Paute - Ecuador

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1 Introduction

In tropical mountains there is a trend towards increasingly larger urban settlements with modern lifestyles (Rudel and Richards 1990) in lieu of small towns with traditional rural lifestyles; historically, the communities of highland Ecuador have experienced changes that mark the human impact on Andean forests (Sarmiento 2010). These changes have been recorded in several processes, such as ecological succession, where intricate transactions of culture/ nature hybrids (e.g., Andean tree line dynamics, biogeography range compression, functional groups diversification, and extinction) imprint ecological legacies in the mountainscape (Sarmiento 2020). This complexity makes it difficult to grapple with these transactions as land use/land cover change only, but promotes a nuanced, profound, and far-reaching farmscape transformation amidst global environmental change (Sarmiento 2008).

We define farmscape as the landscape made up of farms, villages, remnant forest patches, and other attributes related to the agriculture and livestock production of the rural mountainscape. We understand transformation, not only as the change of forest cover, but also as the process by which the physical environment mosaic has been modified, in which the social fabric, economic activities, and cultural values have also been largely changed to a different character altogether.

This mixture of land tenure and resource use prompted an array of bucolic environments (Huttel et al. 1999) that characterize highland Ecuador (Himley 2009), making them exemplary farmscapes (Bebbington 2001). Current ecological theory sees them as novel ecosystems, manufactured landscapes or even fusion (hybrid) ecoregions (Sarmiento 2020; Kremen and Merenlender 2018). We will endeavor to explain how migration forces have enacted erodibility in the communities of the Paute River watershed.

Our study site is known as the Paute River watershed. In archaic Spanish, it refers to a small hill or 'collado' or to a notch or 'abra'. Its toponymy originated in the *Kichwa* language either as *Pawtí to* describe one of the *Kañary* tribes or as *Pawtía* to describe a flowering mountain pass across the cordillera, where Rosacea trees (*Polylepis pauta*) are hyperdominant. The vernacular place name refers to the reported presence of beautiful women with flowers (*paw*) and the locative suffix (*ti* or *tia*) (Villavicencio 1858). Onomastics of the area describe an agrodiverse valley with plenty of orchards and flowery gardens along brooks that cuts a swath through the Andes towards the eastern lowlands of Amazonia. The Paute River watershed belongs to a watershed not bounded by typical political or administrative limits (Griffin 1999), with counties in different provinces (i.e., Azuay, Cañar, and Chimborazo) sharing similar resources, problems, and needs. They also share the settings of high Andean forests, volcanic soils, and rain-fed water, which have traditionally been obtained by an individualistic, utilitarian approach, without integrative management inside the watershed, making it prone to erosion. The lack of an ecosystem approach (Slocombe 1993) in using Paute's resources can be seen in disparate activities of productive sectors, such as electricity, construction, agriculture, and livestock, forming a mosaic of lifestyles and endeavors in their transformation through time and of the political will through administrative priorities. Whilst a great deal of research exists about watershed management in general, very few investigations had been done about the Paute River watershed in describing the changes associated with soil erosion (Harden 1996, 2001), erodibility, and biodiversity, and ecological economics of the farmscapes in southern Ecuador (Viteri 2017). Recently, effects of creating El Collay Commonwealth to conserve some areas of the Paute River watershed have been recently highlighted (Sarmiento et al. 2018) and the investment of revenue for water and electricity production has energized conservation NGOs to work in the area.

Forests in highland Ecuador have almost disappeared from the Sierra region particularly towards the inter-Andean valleys (Young 1998) on the leeward of the continental divide. We seek to characterize farmscape transformation in relation to erodibility, forest cover loss, and human settlements, including migration trends (Donoso and Sarmiento 2019). Notions of global change affecting natural ecosystems are still investigated largely because of the current paradigm of land cover change as one of the drivers of climate change (Pielke 2005; Sarmiento and Kooperman 2019). In most Andean sites, it is the people and their works on the landscape that have defined a clear pattern of ancestral land cover and resource use during millennia (Young 2009; Åkeson et al. 2020). The new paradigm in tropical montology calls for a recognition of the anthropogenic driver (Sarmiento 2000) being as important as climatic or physical drivers for change in the tropical Andes. In the human-dominated landscapes of the Paute River watershed, many of the former forested slopes are now covered with páramos and isolated high Andean monospecific forests of Yagual (*Polylepis incana*) or Pauta *(Polylepis pauta)*. Evidence of anthropogenic change has been monitored with experimental plots, exclusion sampling, fenced quadrants, and other monitoring devices demostrating recovery of the original forest cover in previously páramo-landed grasslands when they are not subjected to traditional burning and grazing (Balslev and Luteyn 1992; White 2013).

The agricultural mapping of southern Ecuador included soil type, climate, vegetation, and land use, with farmscapes identified with their own location.

According to UMACPA (1995b) the Paute River watershed has two types of land use activities: one for the valleys (i.e., lowland) and another for the slopes (i.e., highland). We found this to be simplistic and paradigmatic, reflecting old views of vertical archipelagos in altitudinal arrays, without considering the multiple instances for lowland/highland interactions. In the small flat valleys of the lowlands, medium-sized properties are located on deep soils; here, agribusinesses have greater productivity, and goods are destined for export, such as flowers. Also, some properties in these valleys are devoted to cattle ranching for internal markets such as in the Tarqui valley. Conversely, on the slopes of the highlands where most peasants practice rain-fed agriculture, "minifundios" are located on thin poorer soils with high erodibility. These are very small private plots characterized by subsistence production given plot size and low productivity; erosion problems, and high levels of local consumption of the harvest, support, only partially, their owners through the sale of some surpluses in parochial plazas. Additionally, inadequate road infrastructure and lack of integration with their main provincial markets generate high transportation costs as well as a dearth of public infrastructure. Consequently, low rural standards of living are present and peasants are forced to migrate to cities within Ecuador (i.e., Cuenca, Quito, or Guayaquil), to obtain additional income; but, starting some two decades ago, international emigration occurred towards the United States, Spain, and Italy (Donoso and Sarmiento 2019). Depopulation of the young, particularly male working adults, has changed the Paute River watershed farmscape in unexpected ways. Therefore, physical and human factors have hindered agricultural development in this region (Sarmiento 2002).

By using remote sensing and GIS applications, we seek to understand topics of resource management and socio-ecological pulses and presses generating environmental stress, such as elevation and topographic constrains, cold temperature, lack of precipitations in certain areas, deep slopes and potential soil erosion, overall agricultural limitations, high population density and deforestation, all of them causing serious implications on rural development in the Paute River watershed.

Our general objective is to demonstrate how mountain landscapes in rural areas suffer constant modifications due to dwellers' agricultural practices and migrants' flow impacting the watershed erodibility potential. We hope our findings contribute to fill the gap of knowledge between mountain conservation and population dynamics due to encroaching globalization pressure, migration trends, erodibility, and forest loss.

Our research question asks why mountainous terrain pushes displacement of people towards urban centers affecting the rurality of formerly forested lands, making potential erodibility an important factor to consider in the increased risk and vulnerability of mountain communities highlighted by anthropogenic hazards.

We also question how arable slopes take center stage in analyzing vulnerability due to the high potential erodibility factor with the outmigration/ emigration trend.

Based on shapefiles already made by the Military Geographic Institute of Ecuador (IGM) and by regional institutes, we used ArcMap software, part of the ArcGIS package from ESRI, and its extensions for three-dimensional mapping, space analysis and spatial statistics to create our own Geographical Information System (GIS), from which choropleth, isopleth and raster maps were created for this research; graphic models were created through multimethod research to incorporate social indicators of human geography with physical characteristics of the mountainscape.

To characterize the mountain terrain, a map of altitudes in the Paute River watershed was created from an IGM shapefile of contour lines with elevation data, from which a triangular irregular network (TIN) was created to represent the different elevations in a three-dimensional perspective, allowing for vertical exaggeration. The map of temperatures was made from an IGM shapefile of isothermal curves with temperature data. The map of precipitations was derived from an IGM shapefile of isohyet curves with rainfall data. To create the map of slopes, it was necessary to morph the TIN into a digital elevation model (DEM) from which slopes in degrees were derived after. The map of agricultural limitations by slopes was made, dividing the slopes into two categories: less than 30 degrees and higher than 30 degrees. The map of agricultural limitations in the Paute River watershed was derived from a combination of already existing maps of high-altitude areas and high slopes plus an IGM shapefile of urban areas where agricultural activities are not possible to be developed. Finally, the map of population density is the result of applying the kernel density function into the already mentioned shapefile of urban areas with population data. All maps have a hill shade background to generate a three-dimensional visual effect. Using spatial statistical tools in ArcMap, all areas were summarized according to their hectares and percentages inside the Paute River watershed and all this information was stored in the GIS.

Archival and critical discourse analysis methods were used to gather information of past land use and to document changes as causation of demographic flows in the region. Also, through critical toponymy and biogeography we defined the biocultural diversity present in the watershed, highlighting microrefugia for restoration prospects. Extensive literature review and intimate personal knowledge of local flora, fauna and societies served to frame the correlation of geospatial data with potential erodibility due to the distribution of erosion fronts linked to population dynamics.

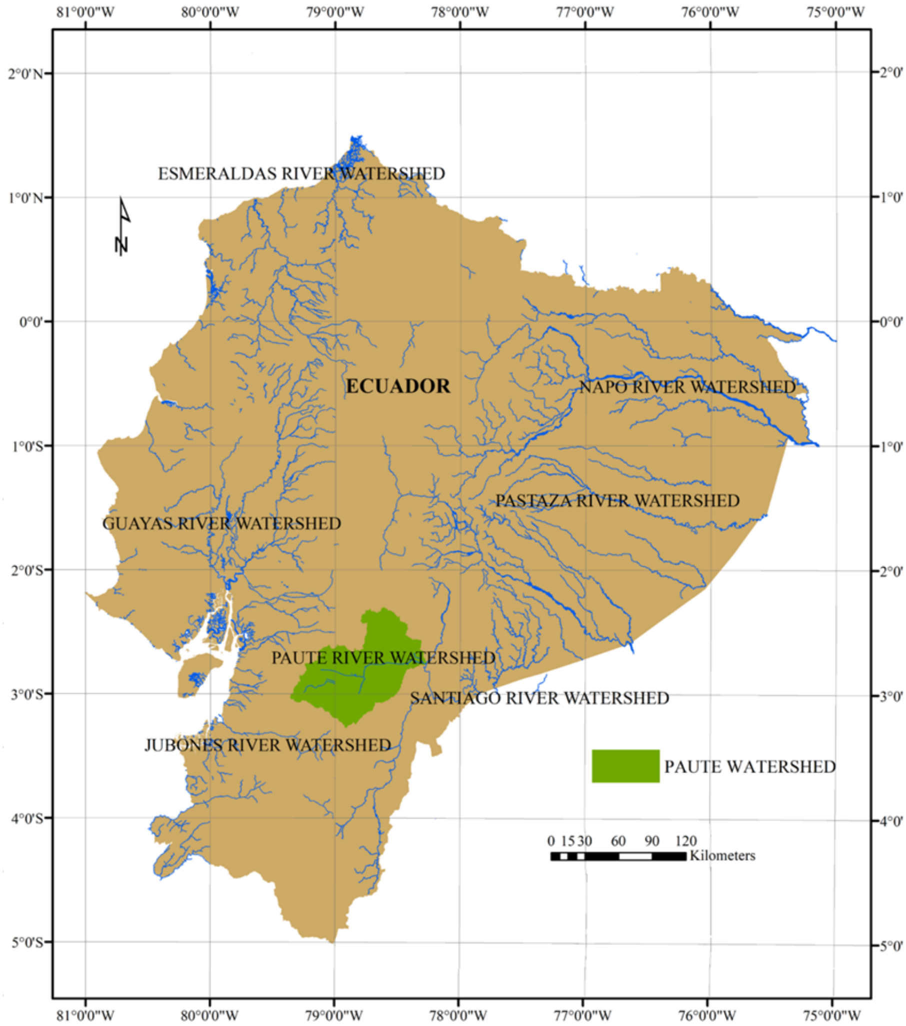

Fig. 1 Map of the Location of the Paute River watershed in Ecuador. Source: Military Geographic Institute (IGM), Ecuador 2017.

2 Study Area

The Paute River watershed is located at a latitude between 2°15'30" and 3°15'30"S and at a longitude between 78°30'30" and 79°20'30"W (Fig. 1). The Paute River occupies a watershed in the Southern Central Andes of Ecuador, and among the ridges of the Curiquingue in the north and the Tarqui in the south. The area of this watershed is approximately 5,131 Km², corresponding to 1.85% of the surface of the country (272,000 Km²). Politically and administratively, the Paute River watershed encompasses several provinces, such as Azuay (74.82%), Cañar (13.31%) and Chimborazo (11.85%). This watershed contains the following counties: Alausí (Achupallas parish) in the province of Chimborazo; Azogues, Biblián, and Deleg in the province of Cañar; and Cuenca, Paute, Guachapala, El Pan, Sevilla de Oro, Gualaceo, Chordeleg, and Sigsig in the province of Azuay. The Paute river traces the Andes towards the Amazon region in the eastern flank of the Andes where the newest Ecuadorian national park has recently been created (Río Negro-Sopladora National Park) increasing the extent of the Protected Areas System of the southeastern Ecuadorian verdant. On the other side, this watershed feeds greater drainage towards the Santiago-Namangoza and finally feeds the greater watershed of the Marañón on route to the Amazon River.

3 Methods

Based on shapefiles already made by the Military Geographic Institute of Ecuador (IGM) and by regional institutes, we used ArcMap software, part of the ArcGIS package from ESRI, and its extensions for three-dimensional mapping, space analysis and spatial statistics to create our own Geographical Information System (GIS), from which choropleth, isopleth and raster maps were created for this research; graphic models were created through multimethod research to incorporate social indicators of human geography with physical characteristics of the mountainscape.

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4 Results

4.1 Altitudes, temperatures and precipitations

In the Equatorial Andes, different temperature regimes exist depending on elevation and latitude. In the specific case of the Paute River watershed, altitude varies between 2,000 and 4,000 m a.s.l., consequently, a thermocline exists in the area, with an adiabatic lapse rate of approximately -1°C for every 200 m. In general, it is possible to say that the climate is moderate, with temperatures fluctuating from 4°C in the highlands, to 16°C in the lowlands; and with the exception of the higher reaches (above 3,400 m), there is no risk of freezing temperatures (Fig. 2).

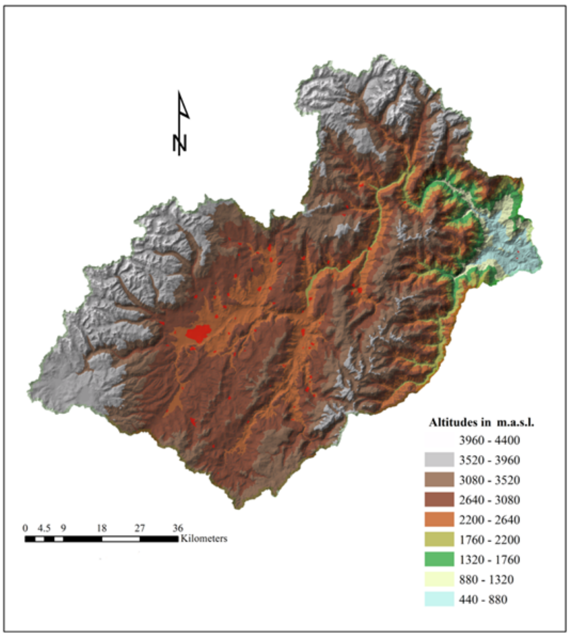

Fig. 2 Map of altitudes in the Paute River Watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

According to the Instituto Nacional de Metereología y Hidrología (INAMHI), there are small monthly temperature changes, not really significant, due to its equatorial proximity, where solar radiation is almost constant with only a few minor changes during the year. Nevertheless, temperature is lower from June to August and slightly higher from December to February (similar to summer and winter in the southern hemisphere seasonal framework). However, instead of true summer and winter seasons, the difference is clearly marked in rainfall counts. The dry season and the rainy season define the cyclical rhythms of the Paute River watershed. In the western and eastern Andes mountains, orographic rains are generated, while the interior of the watershed is drier because of a negative Föhn effect or rain shadow. As important as total yearly precipitation, the distribution of monthly precipitation throughout the year gives seasonality patterns in the Paute River watershed. Towards the east, a hot tropical humid climate predominates; therefore, the climatic regimen in this zone is defined by high evapotranspiration, low atmospheric pressure, and greater precipitation year-round, with a maximum in October with fewer Foehn winds. Towards the west, on the other hand, a dry season predominates due to the influence of the cold Pacific current during part of the year as well as a wet season caused by the presence of hotter waters in the Pacific Ocean from January until May, with a maximum in April, pulsing abundant Fhoen winds into the windward. Figs. 3 and 4 show the yearly dynamics, average temperatures, and precipitation recorded on both sides.

The Paute River watershed presents considerable spatial variations. By quantity and distribution of the rains, the watershed can be differentiated in three areas that coincide with the verticality of the system comprising (1) upper watershed, (2) middle watershed and (3) low watershed. The upper watershed, called *El Cajas,* produces a constant distribution of precipitation during the year because of permanent orographic rains which happen in the higher reaches for which there is no dry period. Towards the middle of the watershed, precipitation shows two maximum values during the year, one from September to November and another one from February to June neither of which are accompanied by much humidity. This middle watershed has a typical "Sierra" rainfall regime presenting two maximum and two minimum values. Finally, the lower watershed is climatically influenced by the "Oriente" regime, which is characterized by high precipitation the entire year, with a dip of rains from November to February, which is typical of the Andean/Amazonian flank.

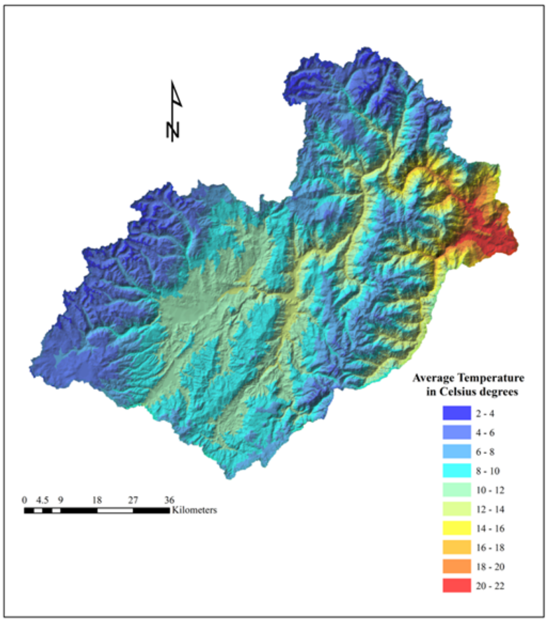

Fig. 3 Map of Average Temperatures in the Paute River Watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

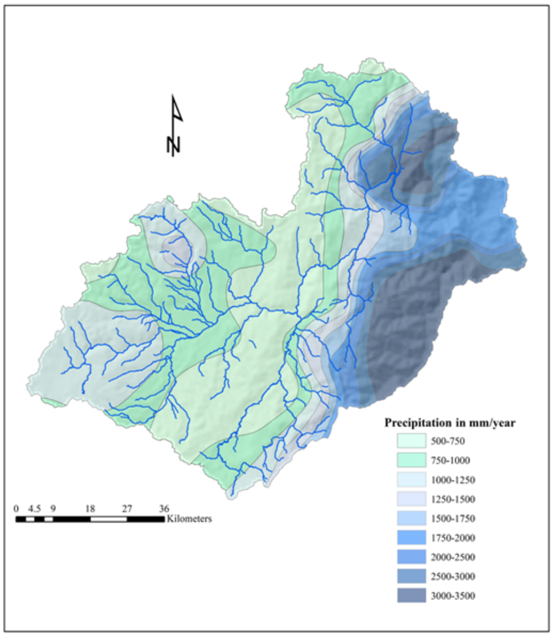

Fig. 4 Map of Average Precipitations in the Paute River watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

4.2 Slopes and erodibility

Because of rugged terrains, the Paute River watershed has a variety of soil types such as Andosols and Histosols at high elevation (above 4,000m); these soils have been formed in places with very humid climates and low temperatures. Vertisols are found in the valleys of Paute, Gualaceo, and Cuenca (2,000 to 3,000m) and are widespread in the middle watershed. Dystricsols exist in the eastern part of the Paute River watershed, where the slopes are inclined, the valleys are narrow, and the climate is humid. Umbricsols appear in areas with strong erodibility caused by high slope topography without vegetation; therefore, its depth is rarely beyond 30 cm. Other soils that exist in the lower watershed are the Luvisols and Cambisols. Steep slopes are evident in the upper watershed, with areas above 60% incline in the headwaters of El Cajas (Figs. 5, 6, and 7). Because of the reduced *Polylepis* cover, the high Andean forest has almost disappeared from the area, with some remnant patches left within the *El Cajas* National Park and other smaller private reserves, such as *Bosque de Mazán*. The grass cover (páramo) that substitutes the forest, imprint erodibility episodes associated with rainfall patterns that creates ecosystem service production function of the páramo areas in relation to potable water supply to the city of Cuenca. This is one of the most important environmental services of the upper watershed, for which the citizens of Cuenca are paying a fee, to help its conservation and management as a protected area (i.e., El Cajas National Park) to the municipal water authority (ETAPA), which also handles telephone and sewage utilities. Historical records of the flow from the four rivers draining the Cuenca valley show episodes of torrential rains and huge sediment load that have accumulated downwards to the adjacent

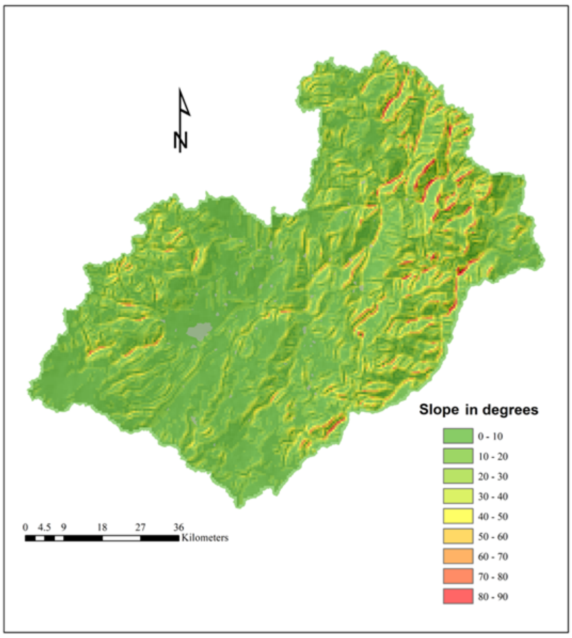

Fig. 5 Map of slopes in the Paute River Watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

Fig. 6 Map of slopes divided in relative flat (≤30°) and hilly regions (>30°, ≤70°) of the Paute River watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

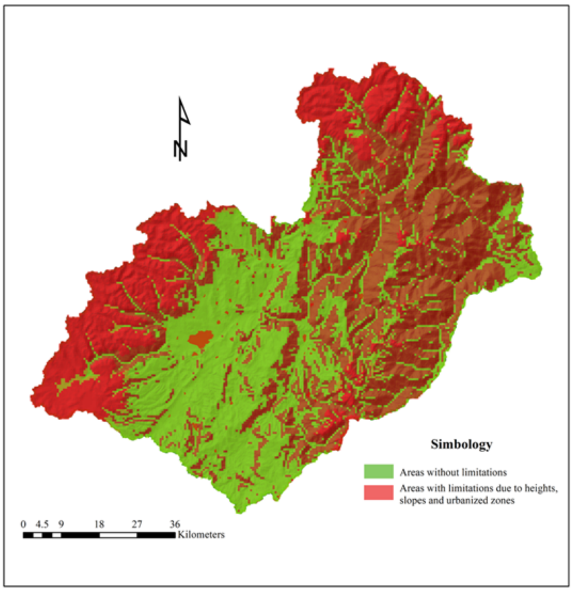

Fig. 7 Agricultural limitations of the Paute River watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

Table 1 Population of counties in the Paute River Watershed. Source: INEC 2015.

County or Perish	Men		Women		Population
	Numbers	%	Numbers	%	
Cuenca	239,497	47.37	266,088	52.63	505,585
Gualaceo	19,481	45.61	23,228	54.39	42,709
Paute	11,881	46.60	13,613	53.40	25,494
Sigsig	11,915	44.28	14,995	55.72	26,910
Chordeleg	5,821	46.28	6,756	53.72	12,577
El pan	1,420	46.77	1,616	53.23	3,036
Sevilla de Oro	2,942	49.96	2,947	50.04	5,889
Guachapala	1,560	45.76	1,849	54.24	3,409
Azogues	32,088	45.80	37,976	54.20	70,064
Biblian	9,193	44.16	11,624	55.84	20,817
Deleg	2,629	43.10	3,471	56.90	6,100
Santiago	4,859	52.28	4,436	47.72	9,295
Achupallas-Alausi	5,004	47.53	5,525	52.47	10,529
Paute River Watershed	348,290	46.91	394,124	53.09	742,414

valleys; in the same vein, records kept at the Miguel Palacios hydroelectric dam show increased rates of sediment load indicating that siltation of the entire reservoir would have imperiled the long-term operation of the dam.

4.3 Human conditions, changing demographics, and farmscapes

The area of Paute River watershed has a population of 620,420, with the county of Azuay being the most populated (394,831 inhabitants) due to the presence of the third largest city in the country, the main city of the Ecuadorian south (Cuenca), representing 63.64% of the total population of the sub region. It is followed in order of descending populace, by the cities of Azogues (10.68% of the population) and Gualaceo (6.65%). The remaining cities individually have less than 5% of the total population of that watershed and all together constitute less than 20% of the population therein. Table 1 shows age distribution and gender parameters of the population of the watershed, which is largely controlled by seasonal employment and migration patterns.

The main economic activities in the Paute River watershed are agriculture and cattle raising, with most people in the countryside being poor (Soussan et al. 2006); but, in small cities, the main activities are commerce, services, and house construction. The poverty levels are higher among women because of the inequality in opportunities to access resources such as training, education, paid work, and capital as well as the minimum amount of participation of women in political and economic decisions (Arellano 2014).

4.3.1 Associated urbanized hotspots

The Paute River watershed has a high population density in its narrow valleys, where the main urban sites are located; for example, the cases of Cuenca and Azogues, provincial capital cities with a fluctuating population whose density is between 10,000 and 50,000 inhabitants per square kilometer, due to the presence of numerous buildings of three or more floors. In the city of Cuenca, the core area and most urbanized center in the watershed, some neighborhoods show a very high density due to the presence of tall apartment buildings. The periphery of Cuenca, Azogues, and Gualaceo present a population density of between 500 and 1,000 inhabitants per square kilometer; therefore, these areas are changing its land use from agricultural to residential (Fig. 8).

The rural areas of the valleys of Cuenca, Azogues, Paute, and Gualaceo are zones of changing demographics because these areas: 1) are affected by a rapid process of urbanization; 2) have numerous small vacation farms and the ever popular "huertos familiares" or small plots with absent owners who obtain groceries from weekend harvests and have small houses for temporary habitation; 3) exhibit many peasant houses and some small settlements dispersed in the upper reaches of the watershed; therefore, in Paute's farmscapes, population densities fluctuate between 100 and 500 inhabitants per square kilometer, which is a very high rural density. Other distant rural areas have a population density between 50 and 100 inhabitants per square kilometer. This low population density is the case along the main highways at elevations below 3,200 m. Densities between 10 and 50 inhabitants per square kilometer

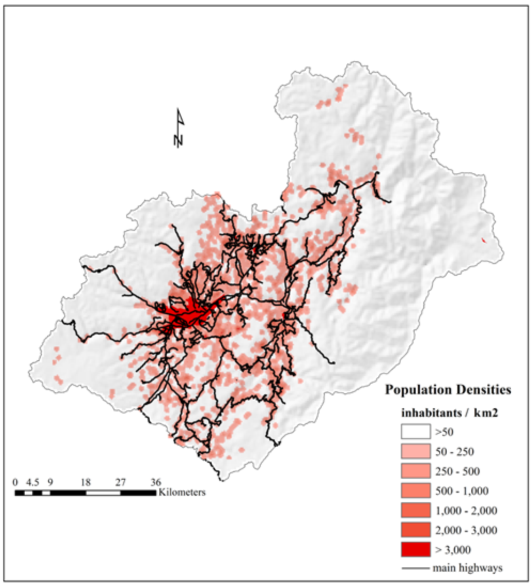

Fig. 8 Population densities in the Paute River watershed. **Source:** Military Geographic Institute (IGM), Ecuador 2017.

are typical of the Tarqui valley in the South. Finally, the distant mountain zones have barely a density of between 5 and 10 inhabitants per square kilometer; but, when elevation surpasses 3,500 m, it is a mere 5 inhabitants per square kilometer, as in *El Cajas* in the West and in *Mailas* in the East, as well as in *Achupallas* parish in the North.

4.3.2 Agricultural Production Units and land tenure

In the Paute River watershed, some 50,000 Agricultural Production Units (APUs) exist, covering an area of approximately 200,000 ha. APUs are defined as productive properties catalogued in the municipal cadastral register, active market supplying, and tax-paying entities. In a way, APUs is a subset of the farmscape, concerned with the taxable, economically viable units only. Fig. 4 shows that 85% of the land parcels are smaller than 3 ha, occupying 20% of the surface area, with an average of 1 ha per APU. With respect to properties smaller than 5 ha, they represent 90% of the total, occupying 25% of the surface area, with an average size of 1.5 ha per APU. Furthermore, the stratum from 5 to 10 ha constitutes 5% of the APUs and 10% of the surface area, with an average of 6.5 ha per each APU. The properties from 10 to 100 ha represent 5% of the APUs, with 25% of the surface, and an average of 25 ha per each APU. And in the stratum of more than 100 ha, they represent 0.5% of the properties, which occupy 40% of the surface area, with 450 ha per APU on average. In synthesis, the main problem of farmscapes is that small farm size (minifundios) in the watershed is ubiquitous due to the constant division of the properties smaller than 3 ha by inheritance or intra-familial transactions.

With respect to land tenure, private property (84.5% of the APUs and 85% of the surface) predominates. Continues in importance the form of mixed owned/ leased possession, with the 13% of the APUs and 13% of the surface area, while the leases constitute 25% of the APUs and just 1% of the surface area (for the most part, these properties had been leasing *al partir*, in other words, peasants cultivate the land but receive only partial profits, the rest is given to the absent landowner). Finally, 0.5% of APUs corresponds to 1% of the surface area and they are properties without titles. Articles 22 and 23 of the Organic Law of Rural Lands and Ancestral Territories of Ecuador recognize the right to property and collective rights (Asamblea Nacional del Ecuador 2016). In fact, Article 22 of the aforementioned law recognizes and guarantees the right to ownership of rural land in all its forms and modalities: public, private, associative, cooperative, communal, and mixed; whereas Article 23 of the same law recognizes and guarantees the right to maintain, preserve, administer, and enjoy the possession of ancestral and communal lands and territories, awarding them in perpetuity free of charge to the commonwealths, communities, and different peoples: indigenous, Afro-Ecuadorians and Montubios, in accordance with the Constitution of Ecuador and with the covenants, agreements, declarations, and other international instruments of collective rights. This communal property is imprescriptible, inalienable, un-attachable and indivisible, and is exempt from the payment of taxes and fees. Also, Article 57 of the Constitution of the Republic of Ecuador in 2008, refers to collective rights where the ownership or possession of the land will be subject to the administration and social control of the territory in accordance with its uses and customs (Barreño Proaño 2017).

Some 50,000 ha are located in the upper watershed and have been analyzed from aerial photographs obtained by PRONAREG-ORSTOM, identifying forests and páramos. Their analysis yielded that the majority of these lands have bushes and forests (34%); transition crops constitute 23% of the surface, páramos 22%, natural pastures 20%, and urban areas 4% of the total surface of this watershed. The political ecology of the area shows that deforestation of the area occurred several centuries ago and that recreational activity for the citizens of Cuenca played a major role in the management of the upper basin. Indeed, hunting and fishing in El Cajas National Recreation Area (category V-IUCN) became legendary. But, from the 1950s onwards, concern for the preservation and safeguarding of the world's cultural and natural heritage increased, although it was not until the 70s that, thanks to the influence of international organizations, the implementation of heritage development policies was favored. From this decade on, a whole philosophy is embodied in a series of measures to promote its protection, conservation, and enhancement. In 1972, the World Heritage Convention was approved and the adhesion of several Latin American countries to it. However, in the 80s, the cultural and natural heritage began to relegate due to latent economic problems. In spite of massive changes, conservation activities by international organizations and legal measures taken, several sites have saved an important part of the Ecuadorian world heritage. UNESCO has encouraged reflection and scientific studies related to heritage have sponsored the validity of international conventions and agreements, the issuance of national laws, and the creation and strengthening of specialized institutions in many countries, including Ecuador (Crespo-Toral 2002). Clearly, the priorities of biodiversity conservation and protection of páramo as wetland, bent the technical criteria to consider the area as a national park (category II-IUCN) with the current priority of preservation of Andean forest and generation of environmental services (i.e., water supply) for the citizens of the watershed, mainly Cuenca. Most visitors today do not realize that the trout they fish, and the páramo they hike on, are not examples of pristine ecosystems, but rather they evidence profound changes brought by the human dimension in the Tropandean landscape making the area a nature-culture hybrid (Sarmiento 2012; White 2013). What is now heralded as one of the most important biosphere reserves in South America, considered one of the iconic national parks of Ecuador, was for decades considered a National Recreation Area with exotic species introduced in areas that were ancestrally highly modified by *Inka, Kañary,* and other pre-Columbian groups that used the sites, generating a vibrant socioecological system in the knott of Azuay.

4.4 Theories of migration applied to the Paute River watershed

Due to a developmental gap, many migrants move between north and south countries (Massey et al. 1999). Thus, emigration becomes one of the best measures to understand economic dynamics. This is because either amenity migrants do not have to work or emigrants need to work; they are not happy with their current status, or the income they generate or they decide to move legally or illegally to another nation, as is the case of the majority of international migrants who move from southern Ecuador (where the Paute River watershed is located) to countries where employment opportunities are more abundant and incomes are higher (Lucas 2005). In the Paute River watershed and other surrounding areas, based on the answers given in the Population Census of Ecuador (2010), migratory processes are associated with the following six theories on migration (Massey et al. 1993): macro-neoclassical economy, micro-neoclassical economy, dual theory of the labor market, network theory, theory of cumulative causation, and theory of migration systems.

4.5 How migration affects the mountain scape

We used these six theories of migration to frame what we describe as the farmscape transformation observed in the Paute River watershed.

4.5.1 Macro-neoclassical economy

It postulates that workers move from one country to another due to differences in wages (Hagen-Zanker 2008). This theory divides the labor market into highly skilled and low skilled workers, who also produce two different migration patterns. Most of these international movements are caused by the labor market and other types of reasons to migrate do not have the same importance. Governments from sending and receiving countries can help to regulate these flows, but the only way to stop the migratory movements will be if the gap between the nations' income decreases and becomes similar (Kurekova 2011).

4.5.2Micro-neoclassical economy

According to this theory, international migration is also generated due to employment rates and income differentials between countries of origin and destination (Cadwallader 1992), but the possibilities of employment and income depend on training, education, and language skills. The cost-benefit calculations at the individual level generate an aggregate total migration. Only if the expected gains are equal to the net cost of migration will the movement stop. The labor market in the destination country is the main reason to migrate and other markets have no relevance. Governments are also influential in international movements through the control of immigration but also because a government can establish wages and salaries (Stahl 1995).

4.5.3 Dual theory of the labor market

In rich societies there is a demand for workers, so there are new immigrants who get jobs from companies and then international salary differences take second place. Because the supply of labor increases, low-level salaries in host nations may not increase, instead wages may be maintained or even decreased, depending on the number of new immigrants. In these cases, the action of governments to stop illegal immigration contradicts the needs of labor demand in postindustrial societies (Porumbescu 2015).

4.5.4 Network theory

It states that once international migration begins, it tends to expand due to the increasingly solid networks of immigrants in destination countries which reach their peak and then decrease. As these networks expand, the costs and risks of migration begin to decrease. It also establishes that wage and employment differentials do not correlate with migratory flows since they are placed in the background in relation to migrant networks. It is difficult for governments to control these migratory flows because networks of migrants are formed and revitalized independent of political regimes with the exception of family reunification policies (Delechat 2001; Haug 2008).

4.5.5 Accumulative cause theory

It says that international migration is a social process that accumulates over time, generating socio-economic and cultural changes in countries of origin and destination. The citizens of destination countries do not want to perform certain types of jobs thereby leaving these tasks for immigrants (Fawcett 1989; Fussell 2010).

4.5.6 Theory of migration systems

It says that relations between countries are political and economic rather than physical, which is why distances lose their meaning, and there may even be multipolar systems, where several developed countries receive people from several developing countries. These international migration systems evolve because economic conditions are variable and some countries can exit, while others can enter these systems (Fawcett 1989).

All these theories are not necessarily contradictory; rather, they complement each other. An individual migrant could perform cost-benefit calculations (micro-neoclassical theory) and at the same time could have relatives abroad willing to receive him and give him accommodation until he gets a job in the country of destination (network theory). Therefore, we consider it a mistake to think that only one of them is the correct paradigm without realizing its structural limitations. In any case, the international emigration of the Paute River watershed and of southern residents, mainly to the United States and Spain, has mainly an economic cause; this very well can be explained by any of the six theses previously expounded upon and much better if it is done with a broader perspective using several or all of these theories.

4.6 International migration

We understand the reasons for emigration to be compelling, including the working conditions of migrants in the destination countries and the existence of immigrant networks abroad. First, studies on the causes or reasons for emigration should focus on the socio-economic situation and the earnings of the people in the places of origin (Bertoli and Marchetta 2014). Second, they must also be based on existing migrant networks and the employment situation of the countries of destination. Continuing with this line of reasoning, we focus on quantitative data obtained from the 2010 Population Census in Ecuador. The objective is to understand the international migration process in two points: origin and destination (Kyle 2000).

Obviously, migratory movements are not exclusive to the Paute River watershed, but are part of a larger socio-economic context that expands to the entire Ecuadorian south and even to the national level. During the last decades of the 20th century and the first of the 21st century, Ecuador has been a country that has not managed to reduce its underemployment (Waters 1997) and consequently its poverty with high levels of social inequality (Llerena Pinto et al. 2015). As a result, migratory flows have been generated abroad, mainly to the United States and Spain (Jokisch and Pribilsky 2002; Kyle and Goldstein 2011), although in the study area there is a notable emigration to the USA. In the case of these two “magnet” countries, it should be noted that they have received labor immigrants, not only from rural and urban areas of Ecuador, but from other countries in Latin America as well (Buján 2003; Massey and Riosmena 2010), generating in these two nations certain types of crops and certain types of companies which are increasingly dominated by immigrant workers (Gratius 2006; Lewis 2003). These countries offer much higher salaries and greater purchasing power in relation to Ecuador, especially the United States, forming immigrant networks that tend to increase over time (Gratton 2007) and to initiate remittance flows that activate the local markets.

4.6.1 Perils of remittance luring

Based on quantitative data and narratives taken from migrant relatives, we understand the causes and effects of people’s movements in the Paute River watershed, which is mostly about illegal migration; it not only generates remittances that stimulate internal markets of the city and even surrounding rural areas, but also generates destruction of nuclear families. We argue that in some U.S. cities, there are networks of Ecuadorian immigrants formed; they gradually grow due to self-reinforcing processes. In the first place, emigration is mostly illegal, migrants travel to a Central American country, then to Mexico, and finally cross to the United States, in a long, expensive, difficult, and dangerous journey (Servan-Mori et al. 2014). Second, the majority of arriving migrants lack credentials to legally work and have no formal higher education (Bertoli et al. 2011), which is why they are perceived as a cheap and docile labor source. Third, these flows are generated by remittances that arrive and make other neighbors, friends or relatives also want to seek better opportunities in the global North (Taylor 1999). The jobs that this low-skilled labor force gets in the United States are seen as "immigrant jobs," and often the citizens of those countries do not want to work in them. When immigrants from a locality, region, or country of origin begin to have a certain number, the multiplier effect of the network begins to take effect, becoming a niche for immigrants of a certain origin, culture, and nationality. A case in point can be found in Camden, New Jersey, where most immigrants have come from the provinces of Azuay and Cañar, and some from the Paute River watershed. Other niches are found in Yonkers or Queens, New York and Hartford, Connecticut.

According to the Population and Housing Census of Ecuador of 1990, the cities of Cuenca, Gualaceo, Paute, and Sigsig in the province of Azuay; the cities of Azogues and Biblian in the province of Cañar and the parish of Achupallas in the city of Alausi (province of Chimborazo) were part of the Paute River watershed. The international emigration data in this watershed showed movement to five continents (because data was not collected at the country level) (Table 2).

Based on data from the 2001 Census, the international emigrants form this watershed moved preferentially to the United States. Finally, the last data census available is the Population and Housing Census of Ecuador of 2010, where it is possible to observe that the Paute River watershed had the same political structure as the past census from the year 2001. Based on data from the 2010 census, the international emigrants form this watershed still were moving preferentially to the United States (Table 3).

4.6.2 Reverse migration or amenity migration

We have to point out the reverse effect of amenity migration that is observed in the region. Unlike rural peasants leaving for poverty reasons to destinations abroad, there is an increased number of foreigners from rich countries that have decided to migrate into the Paute River basin, attracted by the rich biocultural diversity, the rural flair of local culture, organic foodstuffs, and the economic conditions that make expats and retirees attracted to the area. Indeed, several sources for expats and/or retirement living in Europe and the United States, list Cuenca and its surrounding areas as the most attractive places to live in retirement. The oxymoronic economic reality: the poor peasants leaving and the rich retirees coming, makes the Paute River watershed a very curious case of mountainscape transformation where population geographies are colliding with new schemes of collaborative

Table 2 International emigrants from the Paute River watershed according to the population and housing census of Ecuador of 1990. Source: INEC 1990.

Destination continents	Emigrants	
	Numbers	%
America	1.861	85.45
Europa	268	12.30
Asia	43	1.97
Oceania	5	0.23
Africa	1	0.05
Total	2.178	100.00

Table 3 International emigrants from the Paute River watershed according to the Population and Housing Census of Ecuador of 2001 and 2010. Source: INEC 2001 and 2010.

Destination Countries	Emigrants in 2001		Emigrants in 2010	
	Number	%	Number	%
USA	17.460	79.14	13.521	79.25
Spain	2.862	12.97	1619	9.49
Italy	341	1.55	226	1.32
Chile	195	0.88	207	1.21
Canada	150	0.68	177	1.04
UK	69	0.31	158	0.93
Colombia	68	0.31	88	0.52
Germany	62	0.28	77	0.45
Venezuela	45	0.21	64	0.38
Other countries	809	3.67	923	5.41
Total	22.061	100.00	17.060	100.00

enterprising for sustainable development in mountain farmscapes and intermediate cities, known as "imposed mountain development".

4.7 Agricultural limitations and farmscape approach

The landscape transformation with the deleterious effect of introduced species and monoculture is encroaching on the Andean matrix, so much so, that it would be preferable if the conservation of all these Andean highlands could be used for non-consumptive ecosystem services, instead of turning them into pine plantations.

With respect to topographic limitation, the flatter zones with less than 20° of inclination have been used for agriculture or pastures, resulting in minimum erosion processes. Nevertheless, when slopes greater than 20° are placed into production, erosion easily follows; it is preferable to maintain these lands protected with native vegetation, otherwise erosion will begin to act, exacerbated by rains, winds, and farming on steep terrain, until the lands will become derelict, with only non-weathered materials or rocks. Thus, on these very steep slopes, agricultural techniques should operate according to specific norms that minimize environmental impacts, such as drywall terracing or contour planting, restoring agroecological practices of ancestral cultures, such as the *Kañary* and their earthen tufa terracing. Nearly 75% of the Paute River watershed cannot be used for agricultural activities because these areas are found in upper zones or on strong slopes with high erodibility; in contrast, the arable land that constitutes barely 25% of the watershed's surface is capable of supporting agribusiness. From this quarter of surface area, already 4% is in urban use, and the remaining 21% available for farmland use with increased pressure for production of commodified species, such as flowers, ornamentals, even sugar cane, in lieu of the traditional subsistence agricultural products like cereals, potato, and vegetables. These zones are just narrow valleys densely populated where few arable patches exist amidst the urban matrix.

In the leeward area (with Föhn winds) of the lower valley floor having an annual deficit of humidity (annual precipitation averages are lower than annual evapotranspiration averages), most agricultural activities need irrigation during some months to achieve optimum productivity levels. These irrigation systems are complicated to build due to the irregular topography, high operational and maintenance costs, and the lack of economic incentives to favor technological irrigation grants or loans. Nearly 44% of the watershed registers humidity deficit and is one of the biggest problems: these zones with annual humidity deficit are flat, with mild weather, fertile lands, and a good setting for agriculture and livestock activities. The valleys of Paute-Gualaceo have the lowest annual precipitations (800 mm), and the highest evapotranspiration (900-950mm) (Harden 1993; Morris 1985; Staver et al. 1991). Practically all the lowlands below 3,400 m asl. from Biblián to Portete constitute dry areas that need to be irrigated to achieve optimum productivity in different agribusinesses. Lacking enough reservoirs and irrigation channels, pastures of the Tarqui valley have low productivity and are dry. Many fruit-trees and cornfields in the foothills around the valleys of Paute and Gualaceo also have low productivity due to the lack of irrigation.

4.8 Potential land use and land use conflicts

Potential land use implies the determination of what kind of agricultural, livestock, forests, natural areas, or urban uses will exist in a hypothetical landscape with respect to the aptitudes of every zone (Sarmiento et al. 2013). These aptitudes, or ideal land uses, are selected in relation to slope, climate (altitudes, temperatures, precipitation, and evapotranspiration) which create an erodibility factor, as well as with population density and spatial location. Analyzing potential land uses in the Paute River watershed, due to its irregular topography and high erodibility, 63% of the soils should be covered with forests; páramos should correspond to the upper zones in approximately 12% of the territory, while in the valleys with colline slope pastures, should exist (10% of the surface of the basin), the crops (7%), urban areas (4%), and the urban expansion zones (2% of the total surface). Fig. 7 shows an analysis of erodibility and water shortages in the watershed.

The conflicts derived from incompatibilities among the different actual and potential land uses is oriented towards planning actions that may generate future reorganization of rural lands in the Paute River watershed. As it will be posited below, more than half of these territories are under some kind of land use conflict and, in some cases, multiple land use conflicts over the same areas exist. For the elaboration of land use conflicts map, it was necessary to separate from the present land use map those areas containing crops, pastures, forests, and páramos, to establish inside the conflicts that are presented with respect to the potential land use map. Afterwards, all these maps were combined into just one where current and potential erosion were added into this map.

Inside this watershed it is possible to find three classes of erodibility: a) zones that present adequate uses of their lands (due to their coincidence between potential and present uses); b) zones that present land use conflicts (due to their present land use and their potential land use not coinciding); and c) and all the lands that today are eroded or are suffering potential erosion; hence, to be protected immediately. In the Paute River watershed, 13% today is totally eroded, while 29% suffers from varying degrees of degradation processes (potential erosion); therefore, it is possible to say that the areas that present some type of erosion processes correspond to 42% of the total extension of this sub region, similar to other research found in the whole Ecuadorian Andes (Harden 1996). Also, zones that present some type of conflict in their land uses correspond to 10% of the territory of this watershed, giving us a final result of 52% of zones being badly utilized inside this watershed. On the other hand, the zones with adequate land uses constitute 43% of the territory, given that great part of the crops and pastures are located in zones of low slopes or flat areas, as well as some forests growing in slope terrains, while many páramos still remain with abundant grass cover due to the low population density of the highlands.

5 Discussion and Conclusions

This research diagnoses geo-ecological and demographic trends of the Paute River watershed, seeking to characterize the status quo in the rural landscape, carrying out analyses of potential development through GIS techniques, treating problems such as agricultural limitations, land use conflicts, and current and potential erodibility.

Topography and erodibility play an important role in the mountainscape, allowing to distinguish a similar pattern of soils, despite differences in climate. This complex scenario notwithstanding, the human dimension plays a key role in the conservation status of remnant forest patches that survive amidst the matrix of eroded grasslands of the páramo in the upper reaches, making abandoned pasturelands and deforested slopes active fronts of potential erodibility, requiring priority with restoration ecology practices.

5.1 Discussion

While the dominant land use is determined in many cases by climate, there is an increasing contribution of the prevailing agrarian structure in the zone, where the main problems are: the smallholding system, absent ownership, low productivity, lack of economic resources, lack of a capacity-building system for the peasants, and feminization of Andean towns due to the outmigration of seasonal workers to nearby cities or the emigration of the young males to foreign lands. Due to clear correlation among agroecological zones with local climate and erodibility, soil type, and dominant land-use practice, we conclude that, through agroecological zoning and integration of the different dimensions of the Paute farmscapes, it is possible to plan the biocultural heritage conservation of the different mountain areas.

The rural landscape of the Paute River watershed is the result of interrelations between man and nature. In some parts of this basin, old-growth formations exist today, with very little human influence, but the majority of the mountain landscape exhibits the human footprint with intrusive ecological legacy of arrested succession, invasive species, diminishing productivity, overused soils and fallow terrain, ultimately pushing outmigration of poor youth forward. In the different zones of the watershed, humans used and transformed farmscapes according to their changing needs and different economic pressures since the Holocene (White 2013). At present, though, as a preferred destination for expats and retirees the Paute River watershed and the city of Cuenca counter the exodus of young people with waves of newcomers, amenity migrants of old age and deep pockets. The Paute River watershed, therefore, presents land use conflicts as well as limitations to agribusiness activities because of its irregular topography, erodibility, and low precipitation in relation to high demographic changes, especially with imposed mountain development towards its central basin. Also, current and potential erosion greatly affect part of the peripheral basin.

We offer suggestions to help adequately manage the Paute River watershed; the main concern is related to generation of data and information as well as with its applications now that the decentralized governments of the municipalities of the region have coalesced around the El Collay Commonwealth to highlight environmental protection of the watershed and a better usage of ecosystem services. These suggestions tend to generate verifiable and reliable data on natural processes and the update of census data since population and housing information is a product of decadal censuses; therefore, it is important to carry out all possible efforts tending toward improving the local demographic information in this region in quality and quantity.

The approximately 5,000 km^2 of the watershed need an agency of management as one geoecological unit, as it were, since community problems tend to be similar sharing the same natural resources, especially water and confronting erosion risk. Finally, it is important to give farmers adequate training in agribusiness techniques, as well as preferential credits for the agricultural sector; these elements may constitute the basis for the creation of working rural development models; therefore, these investments are vital if the goal is to increase the standards of living of rural families, food security and poverty alleviation of the peasantry.

5.2 Conclusions

We conclude that the Paute River watershed, because of the variety of microclimates and soil types, has a great potential for diverse land uses. But there are limitations for agricultural productivity due to its irregular topography characterized by steep slopes and erosive processes, as well as by land use conflicts, demographic changes, and paradigmatic views that are now pervasive in mountain farmscapes transformed by globalization.

The absence of an adequate territorial analysis in the Paute River watershed prevents management on the basis of planning and more are translated into actions on the watershed to face short-term political problems. On the other hand, ambiguities and legal gaps are the reason why landuse plans cannot advance to date with the task of undertaking modeling approaches to territorial watershed management, the exclusive competence of regional decentralized autonomous governments. This undoubtedly has repercussions due citizen participation is limited, so civil-society organizations are weakened.

While problems await solutions, even more so when a developmental trend with medium-term problems, due to growing demands for water resources and a very critical long-term situation of continued governmental extractives policies, it is an even worse predicament when one considers that mining concessions are done within protected areas. In the face of looming scenarios of climate change, it is important to resume the constitutional course of decentralization through activating planning at the GADs, the decentralized autonomous governments of municipalities.

In this article we suggested some guidelines about control, monitoring and evaluation as well as the economic management necessary to overcome current erodibility problems. Of course, there are concepts and principles that prevail, such as co-responsibility that guarantees sustainable management based on planning and zoning or regulating imposed development scenarios. It is important to emphasize that a responsible attitude of all major players, including the watershed inhabitants, must be, above all, preventive, contaminating less and proactive through environmental education, the use of cleaner technologies in production and the use of advanced technologies for water treatment residuals prior to discharge into the rivers.

6 Recommendations

A modern planning methodology should be implemented, which should be based on using Geographic Information Systems (GIS) and Remote Sensing, that will enable the handling of large quantities of data of different kinds: statistical data as well as maps--historical and otherwise. It is necessary to maintain updated information through small censuses or by means of random sampling techniques to obtain population, economic, and social data. Also, satellite imagery should be used, not only to derive land cover data, vegetation indexes as well as data collection not only through hydrological and meteorological stations, but also from demographic trends, urbanization expansion and potential erodibility risk.

Constant updated information is vital for any type of planning. The effort carried out to obtain an agroecological zonation of this region, as well as agricultural limitations and land use conflicts in the Paute farmscapes, should be used as baseline information for a Watershed Alliance, supporting different local governments (GADs) to carry out adequate and coordinated land use planning as well as different projects about integrated regional development. The work should continue on smaller scales (micro-basin) as well, logically, depending on the different objectives that can exist in each case and involving the participation of the different communities who should be linked to the different processes of development because they are the final beneficiaries. We believe that curving deforestation and soil erosion caused by the burden of increasing demographic change and development trends in the region is imperative.

Finally, it is important to incorporate sustainability criteria: territorial organization, integrated management of natural resources, satisfaction of basic needs and infrastructure, etc. These projects should be carried out by several institutions: big international non-governmental organizations (BINGOs), conservation organizations, regional or local governments (GOs) including the decentralized autonomous administrations of the watershed, small and local environmental non-governmental organizations (ENGOs) of the civil society, or through the creation of a Watershed Alliance where all can be considered as stakeholders. In this case, we favor the enhancement and the support of the participatory approach taken by the Fundación Futuro Latinoamericano in obtaining the voluntary and enthusiastic participation of many municipalities and other stakeholders of the El Collay Commonwealth, that served as a case study to exemplify the application of the Satoyama Initiative of the United Nations University in the Andes (Villanueva et al. 2018; Sarmiento et al. 2018).

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