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Carbon emissions and sequestration produced by deflorestation, forest degration, reforestation, and natural forest recovery, case study

Sergio Alberto Monjardin-Armenta[1], María Alejandra Quintero-Morales[2]✤, Evangelina Ávila-Aceves[1], Lidia Yadira Perez-Aguilar[3], Yedid Guadalupe Zambrano-Medina[1]

[1]Universidad Autónoma de Sinaloa, Facultad de Ciencias de la Tierra y el Espacio, 80007 México.
[2]Universidad Autónoma de Sinaloa, Facultad de Biología, 80007 Culiacán, Sinaloa, México.
[3]Universidad Autónoma de Sinaloa, 80007, Facultad de Informática Culiacán, México.

FOREST MANAGEMENT

ABSTRACT

Background: The degradation and loss of forest cover negatively impact different ecosystems, causing many socio-environmental challenges. This study aims to estimate carbon emissions from deforestation and forest degradation, as well as carbon sequestration through natural forest recovery and reforestation in the North Pacific Basin of Mexico. The methodology follows the guidelines of the good practices of the Intergovernmental Panel on Climate Change, combining activity data with emission and sequestration factors.

Results: The findings indicate a deforestation of 597, 124 ha, a forest degradation of 491,285 ha, resulting in emissions of 9,685.28 Gg CO_2e and 1, 048.49 Gg CO_2e, respectively, as well as reforestation of 5, 328 ha and a natural forest recovery of 97, 112 ha, which originated an absorption of 6.81 Gg CO_2e and 413.38 Gg CO_2e, consecutively.

Conclusion: The highest emissions were associated with the conversion of primary and secondary deciduous forests into annual croplands. Furthermore, primary oak forests transitioned into secondary oak forests. The most affected municipalities include Badiraguato, Mezquital, Guadalupe y Calvo, Durango, Guachochi, Culiacán, and El Fuerte.

Keywords: Carbon sequestration, Land-use change, Carbon emissions, Deforestation, Forest degradation, Natural Forest recovery, Reforestation, Carbon dioxide.

HIGHLIGHTS

- Land use change analysis enabled spatial mapping.
- Mapping at the municipal level enabled the identification of the areas most and least affected by forest processes
- Carbon emissions from deforestation, degradation and uptake from reforestation assessed.
- The highest carbon emissions result from converting forests to agriculture or grasslands.

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✤Corresponding author: alejandra.qm@uas.edu.mx
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INTRODUCTION

Scientific evidence suggests that the quality of human life is closely linked to ecosystems (Tolessa et al., 2017) since they depend on the services provided by these. Such as drinking water, food, climate regulation, and the nutrient cycle, among other things (Gao et al. 2017; Pullanikkatil et al., 2016). However, economic and demographic growth that humans have developed has contributed to a decrease in the quality of these ecosystems, causing adverse reactions such as the loss of biodiversity, soil, and carbon (Cao et al., 2015). Furthermore, deforestation and other exploitative activities disrupt ecosystem balance and hinder natural recovery processes, posing a severe risk to humanity's future (Leal Esper, 2021).

Land-use changes are key drivers of ecosystem stability, decline, or extinction, particularly in forest ecosystems (Zhang et al., 2017). Especially deforestation, which is defined as the conversion of forest land to non-forest land (Oca et al., 2021; UNFCC, 2011), followed by the process of forest degradation, which is caused by selective logging, forest fires, local use of wood for fuel, and livestock grazing, mainly (Achard et al., 2014; Betts et al., 2024). For this reason, deforestation and forest degradation considered within the Agriculture, Forest, and Other Land Uses (AFOLU) sector of the Intergovernmental Panel on Climate Change (IPCC), contribute up to 20% of global emissions of anthropogenic carbon dioxide (CO_2) in the atmosphere (Cadman et al., 2017; IPCC, 2007). Consequently, it is preoccupying since forests serve as essential sinks that can capture close to 20% of anthropogenic carbon emissions globally (Pan et al., 2024).

In contrast, to counteract these two negative forest processes, reforestation is a human-driven process that involves active planting in areas where forest cover previously existed, to restore that cover. Similarly, natural forest recovery is a spontaneous process, without direct human intervention, in which local species colonize an abandoned or disturbed area (Crouzeilles et al., 2017).

The Reducing Emissions from Deforestation and Forest Degradation (REDD+) strategies established by the IPCC play a crucial role in sustainable forest management, conservation, and carbon stock enhancement (Nathan and Pasgaard, 2017). Effective implementation of these strategies requires accurate assessment of forest losses and gains, as well as robust monitoring capabilities.

The latest Global Forest Resources Assessments (FRA) program revealed in its latest assessment that deforestation was reduced in the last decade (2010-2020) to 4.7 million ha per year, due to an increase in forest area due to afforestation or natural expansion of forests (FAO, 2020. However, it does not mean that these last figures are not alarming, since during the period 1990-2000, there was a forest decrease of 7.8 million ha per year and 5.2 million ha during 2000-2010 (FAO, 2020; Keenan et al., 2015).

Additionally, deforestation monitoring capabilities have improved in recent years in tropical countries. That has allowed various research projects on forest processes to develop in different parts of the world (Bartalev et al., 2014; FSI, 2018; Grinand et al., 2013; Hansen et al., 2013; INPE, 2018).

Forest degradation can also lead to significant CO_2 emissions, to the point that in some regions this process emits more emissions than the process of deforestation itself (Hosonuma et al., 2012). Globally, forest degradation is responsible for approximately 5-25% of forest CO_2 emissions (Pearson et al., 2017). This forest degradation is caused by the legal and illegal logging of trees, the use of wood as firewood or for the construction of farms, forest fires, and animal grazing (Hosonuma et al., 2012).

Deforestation and forest degradation have been jointly evaluated for CO_2 emissions, as indicated by the works of (Achard et al., 2014; Pacheco-Angulo et al., 2017). These processes play an essential role in the global carbon cycle, affecting the ability of ecosystems to provide their climate micro-regulation service, water, and biodiversity.

Globally (Achard et al., 2014), studies of forest degradation and implicitly made estimates of carbon loss for the tropical belt. Their results reported a forest loss of 1.514 million hectares, while carbon losses from deforestation from 2000 to 2010 accounted for 10% of carbon emissions from fossil fuel burning. While, Andersen et al. (2016) generated estimates of carbon associated with land-use change and estimated carbon content of land cover. They found that for 2000-2010, 45% of the cover recorded neutral emissions, while 39% of the cover recorded net carbon emissions, followed by 17% as carbon absorbers.

Mexico is among the top 20 countries with the highest deforestation rates worldwide (FAO, 2020; FRA, 2010; Hansen et al., 2013). Not escaping from the world trends described previously, with changes that are generally above the world average in terms of deforestation rates, increase in cultivation areas, grazing, urban expansion, and many others (Rosete-Vergés et al., 2014; Skutsch et al., 2014; Valdez Pérez et al., 2015). Likewise, it is located among the first 50 countries with the highest emissions due to forest degradation (Pearson et al., 2017).

For these reasons, the main objective of this research is to estimate the CO_2 emissions produced by deforestation, forest degradation, and the CO_2 absorptions generated by natural forest recovery and reforestation in the North Pacific basin, Mexico, from 2002 to 2021, and, as a result, to determine which land use and land cover changes generate the most emissions, as well as to identify the municipalities most affected by these forest processes. This region is among the most affected by deforestation and forest degradation due to socio-economic activities such as agriculture, mineral extraction, industry, commerce, and tourism, which have severe impacts on forest ecosystems (CONAGUA, 2012). Therefore, we start from the following hypothesis: "changes in land use and land cover from primary and secondary forests to agricultural land and pastures are conversions that generate higher net CO2e emissions than the carbon balance generated by reforestation and natural forest recovery."

MATERIALS AND METHODS

Study area

The North Pacific Basin covers the entire state of Sinaloa and some municipalities of the states of Durango, Chihuahua, Zacatecas, and Nayarit, in an area of 152, 013 km^2, corresponding to 8.0% of the surface of the Mexican country (Figure 1). Its estimated population is 4, 466, 000 inhabitants (INEGI, 2016a). The increase in the population and socioeconomic activities caused changes in occupation and land-use, which have induced adverse effects, such as soil degradation, a decrease in aquifers by altering the water cycle, and loss of biodiversity (CONAGUA, 2012).

The study area is the most fertile valley in the country, contributing 30.2% of the cultivated food production (CONAGUA, 2015). This agricultural production is mainly due to the water wealth of the region, which has 13 rivers and 11 main dams, which fulfill different functions such as water storage, fishing, and irrigation, and 7 of these serve as hydroelectric dams (CONAGUA, 2012).

Materials

The official maps from series III (2002) and series VII (2021) of Land Use and Vegetation (US&V, by its acronym in Spanish) were used at a scale of 1:250,000 in a Lambert Conformal Conic reference system, which were obtained through INEGI (INEGI, 2016b). The cartography was generated based on photo interpretation by experts and fieldwork to validate and refine the interpretations made, using criteria of physiognomy, floristics, and phenology. The Serie III used Landsat 4 and 5 sensor images, Series VII incorporated Spot 5 and Landsat 8 for photo interpretation. These maps were selected as they closely align with the data from the National Forest and Soil Inventory (INFyS, by its acronym in Spanish), which was done between 2004 and 2009 (CONAFOR and SEMARNAT, 2009). This inventory covers the field sampling stage with 24,659 clusters studied, which in turn comprised 81,665 sampling sites distributed geographically across all vegetation conditions in the country. Also, the data from the National Inventory of Greenhouse Gases of Mexico was used (INGEI, by its acronym in Spanish) (INECC and SEMARNAT, 2015), generated through field surveys in the INFyS as mentioned above.

Methodology

To achieve the stated objective, land-use changes within the basin were analyzed, followed by the estimation of CO_2 emissions resulting from deforestation and forest degradation, as well as CO_2 sequestration from reforestation and natural forest recovery. These estimations were conducted following the IPCC good practice guidelines (IPCC, 2006).

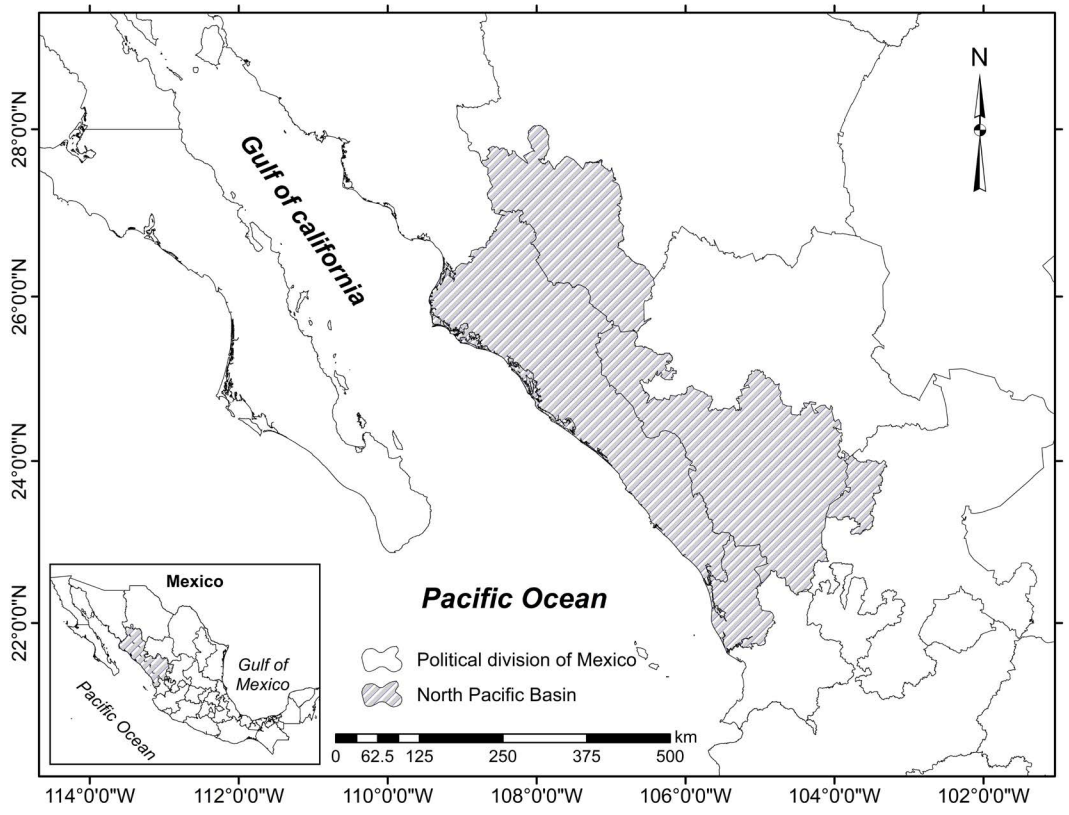

Figure 1: Location of the North Pacific Basin.

Preprocessing of Data

Geometric and topological correction was applied to the US&V maps, and thematic categories were homogenized according to the National Inventory of Greenhouse Gases of Mexico reported to the United Nations Framework Convention on Climate Change (UNFCCC) (INECC and SEMARNAT, 2015). After, the US&V maps were rasterized (vector to raster) with a pixel size of 100 m. This was done to determine the emission and absorption factors at the pixel level, because these factors are measured at the hectare level.

Land-use change

Land-use change analysis between 2002 and 2021 was performed using the cross-tabulation matrix proposed by Pontius et al. (2004). This method allowed the calculation of land-use gains (Equation 1), losses (Equation 2), net change (Equation 3), and total changes (Equation 4) among the categories of the US&V maps.

$$G_{ij} = P_{+j} - P_{jj} \quad (1)$$

$$Lij = Pj+ - Pjj \quad (2)$$

$$D_j = |L_{ij} - G_{ij}| \quad (3)$$

$$DT_j = G_{ij+} - Ljj \quad (4)$$

Where G_{ij} is the gain, P_{+j} is the sum of the column in question, P_{jj} is the value of the main diagonal of the column in issue, L_{ij} is the losses, P_{j+} is the sum of the row in question, D_j it is the net change and DT_j it is the total change.

Estimation of emissions and absorptions of CO_2e

The analysis of CO_2 emission and absorption caused by the forest processes of deforestation, degradation, reforestation, or natural recovery was done by classifying based on the INEGEI. For this analysis, the Activity Data (*AD*) referring to the land-use change of the US&V maps, the Emission Factor (*EF*), which represents forest loss, was also used, as well as the Absorption Factor (*AF*), which means a forest gain (INECC and SEMARNAT, 2015).

These *EF* and *AF* data were acquired from INEGEI, where emissions were estimated for all land-use coverage in Mexico, using field dasometric data, soil type, and vegetation prepared by the INFyS (Annexes 1, 2, 3, 4, 5, and 6). It should be noted that to obtain the EF/AF, the INFyS conducted an uncertainty analysis with 95% statistical reliability using a stratified and systematic cluster sampling design, which indicates that the carbon estimations could have a relative sampling error of between 5% and 10% (CONAFOR and SEMARNAT, 2009).

In accordance with the IPCC good practice guide, the following equations were used to obtain the FE. They used the "stock change" method, measuring the existence of carbon ΔC (Equation 5) in 2 times.

$$\Delta C = \sum ijk((t_2 - t_1)ijk) \quad (5)$$

where *i* corresponds to the type of climate, *j* corresponds to the type of forest, *k* corresponds to land use, Ct_1 is the existence of the carbon sink at time 1 (in tons of carbon) and Ct_2 is the existence of the carbon sink at time 2 (in tons of carbon).

For the FA, the "gain-loss" ΔC (Equation 6) method depended on the rates of loss or gain of the land use area.

$$\Delta C = \sum ijk[A_{ijk} * (C_i - CL)ijk] \quad (6)$$

where A is the land use area, C_i is the rate of carbon gain (in tons per year) and *CL* is the rate of carbon loss (in tons per year).

In such a way that, to know the estimate of CO_2 emission (*E*), the equation (7) was used, and to know the absorption (*A*) of CO_2 (Equation 8), both stipulated by the IPCC guidelines. The amounts of CO_2 emitted or absorbed were converted to Carbon Dioxide Equivalent (CO_{2e}) according to (WRI, 2005; INECC; SEMARNAT, 2015).

$$E = EF * AD \quad (7)$$

$$A = AF * AD \quad (8)$$

RESULTS

Preprocessing of data, and Land-use change

The first result was the homogenized US&V maps according to the INGEI of Mexico (Figure 2). The variations between categories were determined by analyzing the changes between both maps through a cross-tabulation matrix. For example, in the human settlements category (5), in 2002 its area was 75,014 ha, while in 2021 it was 109,354 ha, that is, there was a gain between 2002 and 2021 of 36,356 ha. Said profits are generated mainly from the annual agricultural (2) and pasture (20) categories with 26,552 ha and 4,075 ha, respectively. Nevertheless, human settlements remained stable at 72,998 ha. When comparing this value with the superficial value of the first date, a differential of 2,016 ha went from this category to annual agricultural land (2) and perennial agricultural land (3) with 1,607 ha and 79 ha, respectively.

The forest covers with the greatest losses were the primary coniferous forest (7) with 477,019 ha, the primary oak forest (9) with 348,392 ha, and the primary deciduous forest (21) with 284,505 ha. On the other hand, the categories that presented the most significant gains were annual agricultural (2) with 409,026 ha, secondary coniferous forest (8) with 359,687 ha, and secondary oak forest (10) with 193,149 ha.

The greatest persistence occurred in the primary coniferous forest (7) with 3,264,158 ha, in annual agricultural (2) with 2,596,434 ha, and in the primary deciduous forest (21) with 2,080,985 ha. The categories with the greatest net variation were the secondary coniferous forest (8) with 297,559 ha, the primary coniferous forest (7) with 274,654 ha, and the primary oak forest (9) with 175,037 ha (Table 1).

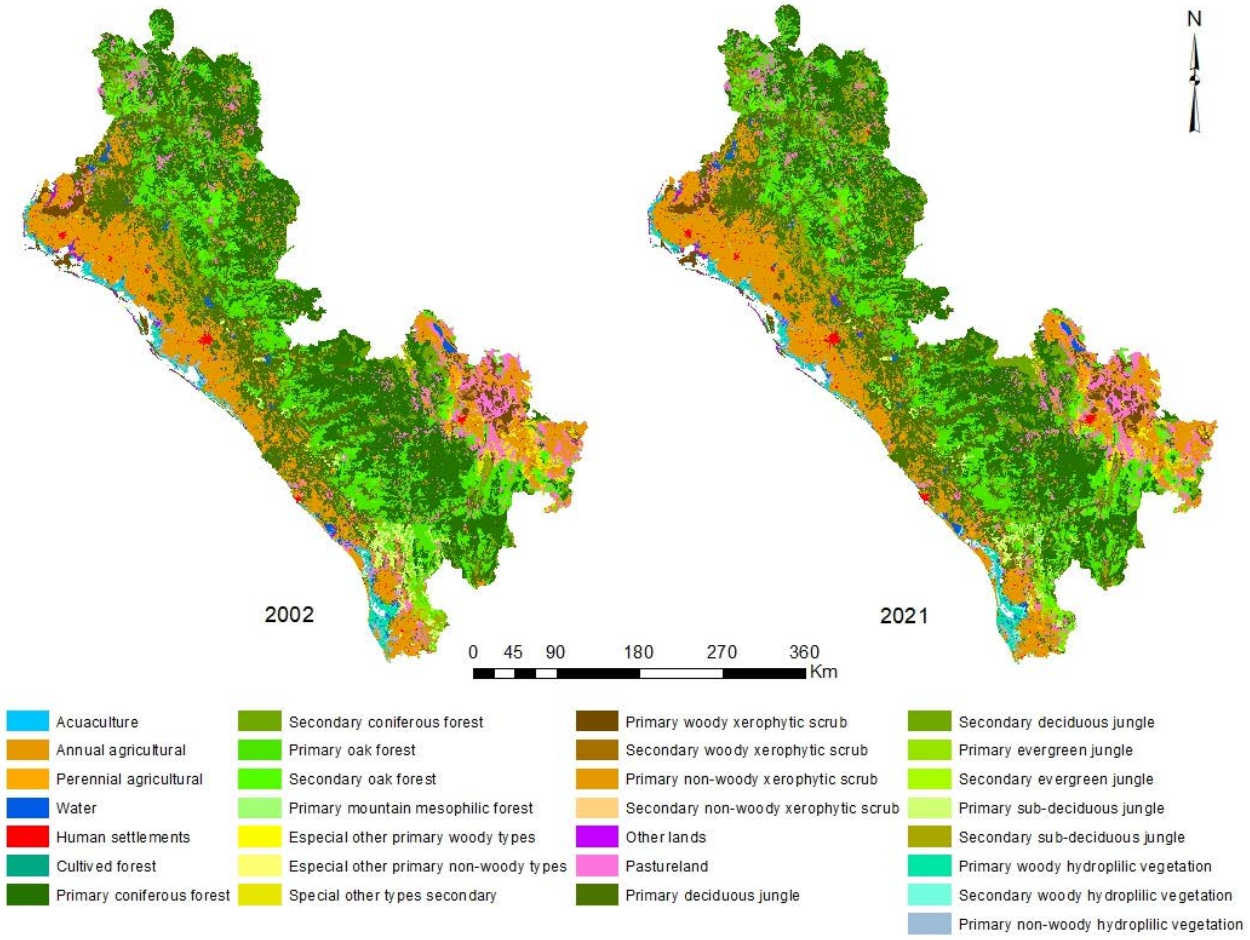

Figure 2: Homogenized US&V maps.

Regarding the changes that occurred at the municipal level (Figure 3), there was greater deforestation in Badiraguato at 51,067 ha, followed by Culiacán at 39,731 ha, El Fuerte at 35,067 ha, at Sombrerete 28,308 ha, and Tamazula at 26,680 ha. The municipalities with the most degraded forest area were Mezquital 62,434 ha, Guadalupe y Calvo 52,252 ha, Durango 50,676 ha, Guachochi 50,535 ha, and San Dimas 40,760 ha. Continuing with the forest processes that occurred, the municipalities that presented the greatest natural recovery were Mezquital 13, 191 ha, Durango 9, 821 ha, Guadalupe y Calvo 9, 662 ha, Ruiz 8, 778 ha, and Rosario 7, 418 ha. On the other hand, the most representative reforested areas were observed in Santiago Ixcuintla 1,586 ha, Angostura 1,212 ha, Navolato 922 ha, Tuxpan 337 ha, and Ahome 324 ha.

This analysis also gave us an overview of the forest processes. For example, 18.08% of secondary jungles, 5.87% of primary Jungles, 4.10% of secondary forests, and 2.01% of primary forests were deforested between 2002 and 2021.

Concerning the gain represented by the natural conversion within the same categories of forest and jungles, 0.92% of secondary forest went to the primary forest, and 1.55% of secondary jungle went to the primary jungle. In contrast, the reforestation of forests and jungles taken in this study as the transformation of other land-use to forest or jungle categories, where 1.47% of different categories went to primary forest, 2.85% to primary Jungle, 14.48% secondary forest, and 15.90% secondary jungle.

In general, it can be determined that the conversion of primary and secondary deciduous forests into agricultural land is the main factor driving carbon emissions in the region, which validates the study conducted by Plata-Rocha et al. (2021), which determines that the expansion of the agricultural frontier is the main cause of forest cover loss in the North Pacific Basin.

CO_2 emissions estimation

The forest processes resulted in both CO_2 emissions and absorption. The estimated emission from the deforestation of 597,124 ha was 9,685.28 Gg of CO2e. Most emissions came from changes such as primary deciduous jungle to annual agriculture with 9,065.41 Gg CO2e, primary coniferous forest to grassland with 7,002.51 Gg CO2e, primary coniferous forest to annual agriculture with 4,771.24 Gg CO2e, secondary deciduous jungle to annual agriculture with 4,106.71 Gg CO2e, and primary oak forest to grassland

with 1,713.87 Gg CO2e. Forest degradation contributed 1,048.49 Gg of CO2e from 491,285 hectares of degraded land. Influential transitions included primary deciduous jungle to secondary deciduous jungle with 662.93 Gg CO2e, primary oak forest to secondary oak forest with 138.14 Gg CO2e, primary coniferous forest to secondary coniferous forest with 115.99 Gg CO2e, primary woody hydrophilic vegetation to secondary woody hydrophilic vegetation with 55.62 Gg CO2e, and primary deciduous jungle to secondary deciduous jungle with 45.85 Gg CO2e (Table 2).

In this evaluated period there was also absorption of CO_2, in such a way that the estimate for the reforestation process in 5,328 ha was 6.81 Gg of CO_2e, this is due to the following transitions primary to non-woody hydrophilic vegetation to secondary deciduous jungle with 4.36 Gg of CO_2e, primary non-woody hydrophilic vegetation to primary woody hydrophilic vegetation with 1.38 Gg of CO_2e and primary non-woody xeric scrub to primary woody xeric scrub with 0.26 Gg of CO_2e. Continuing with the absorption estimate of 97, 112 ha of the natural recovery forest process was 413.38 Gg of CO_2e, the most representative transitions being secondary deciduous jungle to primary deciduous jungle with 202.03 Gg of CO_2e, secondary coniferous forest to primary coniferous forest with 107.15 Gg of CO_2e and secondary deciduous jungle to primary deciduous jungle with 53.59 Gg of CO_2e (Table 2).

Table 1: Parameters of land-use change (2002–2021), in hectares.

Category	Sumatory 2002	Sumatory 2021	Losses	Gains	Persistence	Net change	Total change
1	45,981	77,136	6,372	37,527	39,609	-31,155	43,899
2	2,918,827	3,005,460	322,393	409,026	2,596,434	-86,633	731,419
3	31,316	47,615	5,287	21,586	26,029	-16,299	26,873
4	120,031	119,712	20,807	20,488	99,224	319	41,295
5	75,014	109,354	2,016	36,356	72,998	-34,340	38,372
6	97	320	2	225	95	-223	227
7	3,741,177	3,466,523	477,019	202,365	3,264,158	274,654	679,384
8	527,994	825,553	62,128	359,687	465,866	-297,559	421,815
9	2,086,390	1,911,353	348,392	173,355	1,737,998	175,037	521,747
10	396,264	522,362	67,051	193,149	329,213	-126,098	260,200
11	12,762	21,807	2,502	11,547	10,260	-9,045	14,049
12	8,499	7,559	2,401	1,461	6,098	940	3,862
13	10,106	8,657	2,472	1,023	7,634	1,449	3,495
14	194,286	187,560	46,680	39,954	147,606	6,726	86,634
15	306,552	283,989	28,451	5,888	278,101	22,563	34,339
16	39,065	36,165	11,165	8,265	27,900	2,900	19,430
17	29,269	20,358	9,944	1,033	19,325	8,911	10,977
18	6,148	7,267	3,486	4,605	2,662	-1,119	8,091
19	43,540	48,728	11,109	16,297	32,431	-5,188	27,406
20	920,174	875,773	230,923	186,522	689,251	44,401	417,445
21	2,365,490	2,237,813	284,505	156,828	2,080,985	127,677	441,333
22	504,236	577,304	111,549	184,617	392,687	-73,068	296,166
23	48,909	58,373	10,585	20,049	38,324	-9,464	30,634
24	2,825	6,747	607	4,529	2,218	-3,922	5,136
25	216,036	230,677	45,449	60,090	170,587	-14,641	105,539
26	79,957	40,525	57,096	17,664	22,861	39,432	74,760
27	175,142	164,466	29,002	18,326	146,140	10,676	47,328
28	13,622	29,987	5,630	21,995	7,992	-16,365	27,625
29	79,630	56,964	30,629	7,963	49,001	22,666	38,592

Leyend: Acuaculture (**1**), Annual agricultural (**2**), Perennial agricultural (**3**), Water (**4**), Human settlements (**5**), Cultived forest (**6**), Primary coniferous forest (**7**), Secondary coniferous forest (**8**), Primary oak forest (**9**), Secondary oak forest (**10**), Primary montain mesophilic forest (**11**), Special other primary woody types (**12**), Special other primary non-woody types (**13**), Special other types secondary (**14**), Primary woody xerophylic scrub (**15**), Secondary woody xerophylic scrub (**16**), Primary non- woody xerophylic scrub (**17**), Secondary non-woody xerophylic scrub (**18**), Other lands (**19**), Pastureland (**20**), Primary deciduous jungle (**21**), Secondary deciduous jungle (**22**), Primary evergreen jungle (**23**), Secondary evergreen jungle (**24**), Primary sub-deciduous jungle (**25**), Secondary sub-deciduous jungle (**26**), Primary woody hydrophilic vegetation (**27**), Secondary woody hydrophilic vegetation (**28**), Primary non-woody hydrophilic vegetation (**29**).

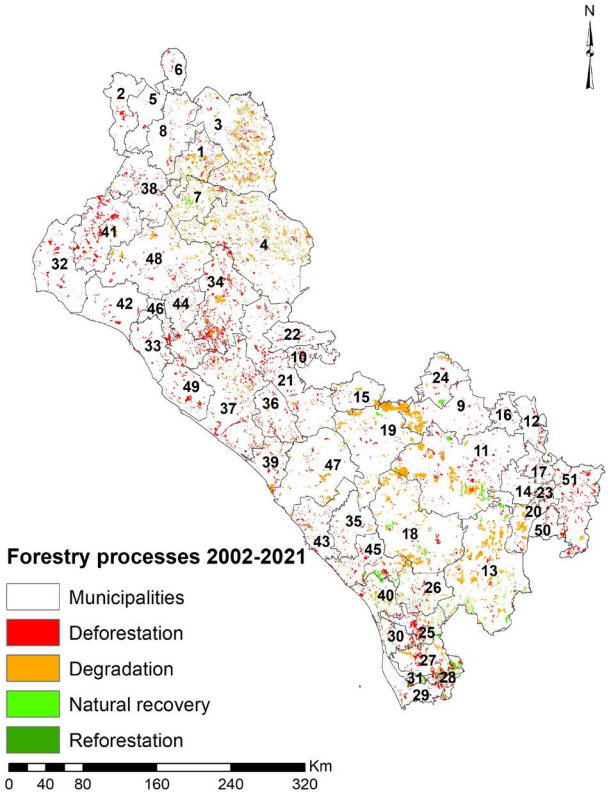

Figure 3: Forest processes.

Leyend (1 Batopilas; 2 Chínipas; 3 Guachochi; 4 Guadalupe y Calvo; 5 Guazapares; 6 Maguarichi; 7 Morelos; 8 Urique; 9 Canatlán; 10 Canelas; 11 Durango; 12 Guadalupe Victoria; 13 Mezquital; 14 Nombre de Dios; 15 Otáez; 16 Pánuco de Coronado; 17 Poanas; 18 Pueblo Nuevo; 19 San Dimas; 20 Súchil; 21 Tamazula; 22 Topia; 23 Vicente Guerrero; 24 Nuevo Ideal; 25 Acaponeta; 26 Huajicori; 27 Rosamorada; 28 Ruíz; 29 Santiago Ixcuintla; 30 Tecuala; 31 Tuxpan; 32 Ahome; 33 Angostura; 34 Badiraguato; 35 Concordia; 36 Cosalá; 37 Culiacán; 38 Choix; 39 Elota; 40 Escuinapa; 41 El Fuerte; 42 Guasave; 43 Mazatlán; 44 Mocorito; 45 Rosario; 46 Salvador Alvarado; 47 San Ignacio; 48 Sinaloa; 49 Navolato; 50 Chalchihuites; 51 Sombrerete).

Regarding the emission and absorption results obtained in the present evaluation period, they indicate that the emission was greater, with an estimate of 10,733.77 Gg of CO_2e, than the absorption, with 420.19 Gg of CO_2e, with a net balance of 10,313.58 Gg of CO_2e.

DISCUSSION

Mexico is among the first 20 countries (FAO, 2020; Hansen et al., 2013) with more significant loss of forest and jungle cover worldwide, and mid the first 50 countries with the highest forest degradation (Pearson et al., 2017).

In this regard, at the national level, the study by Masera et al. (1997), is an important reference point for carbon emission estimates in the mid-1980s in contrast to scenarios for the year 2025. This revealed that 804,000 hectares per year suffered disturbance in Mexico, of which 668,000 hectares were due to deforestation, generating net carbon emissions of 52 million TCO_2/year, this already includes carbon gains from reforestation and natural forest recovery. Comparing these results with the present study, we have lower values per unit area, since 9,685 Gg CO2e of emissions were estimated for 597,124 hectares.

Návar-Chaidez, (2008) assessed the change in the Tamaulipas forest to other land uses and land cover and determined the significant contribution of CO_2 flux, and that deforestation could be responsible for 41% of national emissions in semi-arid ecosystems, which reinforces our results indicating that arid and semi-arid areas contribute significantly by surface area.

Pompa-García and Sigala-Rodríguez (2017) highlighted the lack of comprehensive syntheses on carbon sequestration rates by species in Mexico, which limits the references available for comparative studies. This justifies the significance of our results, as they provide quantitative and spatial data for a specific region of Mexico.

Another study conducted in Brazil by Csillik et al. (2024), indicates that 17% of emissions are the result of direct deforestation, while the remaining 83% come from forest degradation and disturbance, including fires, selective logging, and natural events, highlighting that degradation is the largest source of emissions in this region. In contrast to our results, the opposite occurred, as deforestation was responsible for approximately 90% of emissions, and 10% corresponded to forest degradation.

Globally, forest ecosystems absorb about 9.53 $GtCO_2e$/year, while deforestation and degradation contribute 5.87 $GtCO_2e$, leaving a net positive balance (VIRGILIO, 2010). On the other hand, our results show a significant negative net balance (10,313 Gg CO_2e), indicating that locally, the North Pacific Basin is a net source of emissions.

Mature forests tend to act as carbon sinks in the process of storing carbon as above and below-ground biomass (Munawar et al., 2015). As for the estimated carbon emissions of 9,685.28 Gg of CO_2e for the 597,124 ha. Our estimates are found in the published by (Pearson et al., 2017) which reports 0 a 5 million Mg CO_2 per year of total degradation emissions for the area of this study, associated with 15-50 million Mg CO_2e/yr Timber Emissions, which, for Mexico, represents less than 50 Mt CO_2/yr of emissions from wood, followed by firewood and fires.

Likewise, Tölgyesi et al. (2025) show that the potential for climate mitigation through ecosystem restoration is insufficient, as it ranges between 3.7% and 17.6% of cumulative human emissions, and that the benefits of forest cover should be considered more in terms of biodiversity and resilience than as a primary climate solution. This demonstrates that reforestation efforts are valuable but must be complemented by conservation, sustainable management, and emissions reduction strategies following recommendations aimed at promoting REDD+ and even more local-administrative management, such as at the municipal level, as indicated in this study.

On the other hand, it is worth mentioning that the most affected municipalities in the basin in terms of forest and jungle loss match the municipalities that are the hot spot of deforestation most critical in the state of Sinaloa by Monjardin-Armenta et al. (2016).

Table 2: Emissions and absorptions of CO_2 from the North Pacific basin.

Forest processes	Live Biomass Carbon t/C	Carbon Roots t/C	Total Carbon t/C	Emissions (Gg CO_2)
Deforestation	-2114742.4	-526698.44	-2641440.87	9685.28
Degradation	-229996.76	-55955.03	-285951.79	1048.49
Natural recovery	92068.88	20671.33	112740.21	-413.338
Reforestation	1494.86	362.75	1857.60	-6.81

t/C = Tons of Carbon; Gg= Giga-grams; CO_2 e = Carbon dioxide equivalent

Our results for CO_2 emissions and removals in the period 2002-2021 reveal a higher estimate of emissions of 10,733.77 Gg of CO_2e, compared to the absorption estimates of 420.16 Gg of CO_2e, with a net balance of 10,313.58 Gg of CO_2e. The forestry processes that occurred during the period under evaluation were as follows 9,685.28 Gg of CO_2e in 597,124 ha, with the largest transition from primary coniferous forest to grassland. This change in cover from forest to pasture causes an 8% increase in soil organic carbon (Guo & Gifford, 2002), while extensive agriculture causes the loss of up to 50% of soil carbon (Andersen et al., 2016). The change from forest cover to agriculture for food production leads to high CO_2 emissions rates, similar those reported by Khan et al. (2020).

Degradation and deforestation can be attributed to a variety of causes, such as disease, floods, fires, and storms. However, anthropogenic activities such as illegal logging, agricultural expansion, and lack of government policy enforcement have the greatest impact on CO_2 emissions from deforestation (Khan et al., 2020).

In this aspect, we agree with the recommendations made by (Khan et al., 2020), that, to continue with sustainable forest management practices, the REDD+ incentive (Collins et al., 2022; Park and Yeo-Ch, 2012). Should be extended to localities at the municipal level, to obtain carbon credits, as well as to reforest deforested areas, both in municipalities with forest cover and in those with greater agricultural land cover (Park and Yeo-Ch, 2012).

At the municipal level in Mexico, there are indications of difficulties in developing the REDD+ program due to weak local governance, where conflicts have been reported arising from the implementation of policies that do not take into account traditional forms of management or local agrarian governance, as (Klooster and Masera, 2000) points out, community forest management projects have the capacity to mitigate deforestation and increase forest cover. For example, although REDD+ has promoted the creation of inter-municipal coordination boards between municipalities, CONAFOR, NGOs, and communities, these structures remain limited to pilot areas and do not always guarantee equitable participation or community benefits (Amico and Trench, 2016). Furthermore, during the REDD+ preparation phase (2007–2017), serious deficiencies have been documented in the inclusion of rural and indigenous communities, especially, regard to free, prior, and informed consent, thus affecting the legitimacy and effectiveness of national REDD+ policies (Almanza-Alcalde et al., 2022). Therefore, the results of this study serve to plan sustainable forest management, conservation, and increased forest cover in a more appropriate manner, as they quantitatively determine the areas that would be a priority for attention within each municipality.

Limitations

One of the limitations of this study is that, to determine the ADs, we started from the changes determined from the land use and vegetation mapping at a scale of 1:250,000, which does not provide an analysis of uncertainty and validation of cartographic accuracy. This may overestimate carbon emission and sequestration results, although EF/AF were determined with a 95% confidence level. Therefore, the results obtained may vary within a reasonable confidence interval, as the methodologies recommended by the scientific literature and the guidelines of the IPCC and the REDD+ program were followed.

CONCLUSIONS

In general, this study identified and spatially quantified the carbon balance associated with deforestation, forest degradation, reforestation, and natural forest recovery of different forest cover types in the North Pacific Basin of Mexico between 2002 and 2021, indicating a net negative balance of 10,313.58 $GgCO_2e$, which confirms that changes in land use and land cover, particularly the conversion of primary and secondary deciduous forests to agricultural land, are the main driver of carbon emissions in the region. Although reforestation and natural forest recovery processes favored carbon sequestration, their effect was not sufficient to offset the magnitude of emissions from deforestation and forest degradation.

The cross-tabulation matrix helped to evaluate in detail the changes generated in the land-use cover. It also allowed specialists to focus attention on the most critical transitions and facilitate the understanding of the different processes that occur on the land-cover, such as the forest processes. According to this analysis of changes, a map of forest processes was generated, with affected and benefited surfaces determined at the municipal level.

When compared with the few national and international studies available, the results coincide with evidence that deforestation in Mexico continues to be a significant source of greenhouse gases. However, degradation also contributes approximately 10% of total emissions, which is less than that reported in tropical regions such as the Amazon, where degradation can even exceed

the impact of deforestation. Therefore, it was generally determined that the North Pacific Basin is a net source of CO_2 emissions, which implies integrating policies to promote sustainable forest management and the conservation of forest ecosystems to progress toward climate neutrality.

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AUTHORSHIP CONTRIBUTION

Project Idea: SAMA.; MAQM

Funding: SAMA.; MAQM

Database:SAMA.; MAQM.; EAA

Processing: SAMA.; MAQM

Analysis: SAMA.; MAQM.; EAA.; LYPA

Writing: SAMA.; MAQM

Validation: SAMA, EAA, LYPA

Review: SAMA.; MAQM

DATA AVAILABILITY

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

COMPETING INTERESTS

The authors declare no competing interests.

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ANNEX 1: FOREST LANDS REMAINING AS FOREST LANDS.

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
Status		Forest land/Reporting subcategory	Ton/C/year	Ton/C/year
PERMANENCES	Primary coniferous forest	Primary coniferous forest	0,432586566	0,094297388
	Secondary coniferous forest	Secondary coniferous forest	0,30146358	0,066956374
	Primary oak forest	Primary oak forest	0,461736734	0,115675606
	Secondary oak forest	Secondary oak forest	0,483981032	0,124262132
	Primary montain mesophilic foresty	Primary montain mesophilic foresty	1,462335356	0,342578187
	Secondary montain mesophilic foresty	Secondary montain mesophilic foresty	0,295151494	0,071960451
	Primary evergreen jungle	Primary evergreen jungle	0,483704515	0,111601646
	Secondary evergreen jungle	Secondary evergreen jungle	0,626166607	0,140073675
	Primary sub-deciduous jungle	Primary sub-deciduous jungle	1,355714996	0,311721643
	Secondary sub-deciduous jungle	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary deciduous jungle	Primary deciduous jungle	0,414738123	0,096805142
	Secondary deciduous jungle	Secondary deciduous jungle	0,660096078	0,15198938
	Cultived forest	Cultived forest	0	0
	Primary woody xerophylic scrub	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Secondary woody xerophylic scrub	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Primary woody hydrophilic vegetation	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary woody hydrophilic vegetation	Secondary woody hydrophilic vegetation	1,028589094	0,233674469
	Special other primary woody types	Special other primary woody types	-0,406353045	-0,104205546
	Special other secondary woody types	Special other secondary woody types	0,087234173	0,021375884
	Primary oak forest	Primary coniferous forest	0,432586566	0,094297388
	Secondary oak forest	Primary coniferous forest	0,432586566	0,094297388
	Primary montain mesophilic foresty	Primary coniferous forest	0,432586566	0,094297388
	Secondary montain mesophilic foresty	Primary coniferous forest	0,432586566	0,094297388
	Primary evergreen jungle	Primary coniferous forest	0,432586566	0,094297388
	Primary sub-deciduous jungle	Primary coniferous forest	0,432586566	0,094297388
	Secondary sub-deciduous jungle	Primary coniferous forest	0,432586566	0,094297388
	Primary deciduous jungle	Primary coniferous forest	0,432586566	0,094297388
	Secondary deciduous jungle	Primary coniferous forest	0,432586566	0,094297388
	Cultived forest	Primary coniferous forest	0,432586566	0,094297388
	Primary woody xerophylic scrub	Primary coniferous forest	0,432586566	0,094297388
	Secondary woody xerophylic scrub	Primary coniferous forest	0,432586566	0,094297388
	Primary oak forest	Secondary coniferous forest	0,30146358	0,066956374
	Secondary oak forest	Secondary coniferous forest	0,30146358	0,066956374
	Primary montain mesophilic forestv	Secondary coniferous forest	0,30146358	0,066956374
	Primary sub-deciduous jungle	Secondary coniferous forest	0,30146358	0,066956374
	Primary deciduous jungle	Secondary coniferous forest	0,30146358	0,066956374
	Secondary deciduous jungle	Secondary coniferous forest	0,30146358	0,066956374
	Primary woody xerophylic scrub	Secondary coniferous forest	0,30146358	0,066956374

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
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	Secondary coniferous forest	Primary oak forest	0,461736734	0,115675606
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	Secondary evergreen jungle	Primary oak forest	0,461736734	0,115675606
	Primary sub-deciduous jungle	Primary oak forest	0,461736734	0,115675606
	Secondary sub-deciduous jungle	Primary oak forest	0,461736734	0,115675606
	Primary deciduous jungle	Primary oak forest	0,461736734	0,115675606
	Secondary deciduous jungle	Primary oak forest	0,461736734	0,115675606
	Primary woody xerophylic scrub	Primary oak forest	0,461736734	0,115675606
	Secondary woody xerophylic scrub	Primary oak forest	0,461736734	0,115675606
	Special other primary woody types	Primary oak forest	0,461736734	0,115675606
	Special other secondary woody types	Primary oak forest	0,461736734	0,115675606
	Primary coniferous forest	Secondary oak forest	0,483981032	0,124262132
	Secondary coniferous forest	Secondary oak forest	0,483981032	0,124262132
	Secondary evergreen jungle	Secondary oak forest	0,483981032	0,124262132
	Primary sub-deciduous jungle	Secondary oak forest	0,483981032	0,124262132
	Secondary sub-deciduous jungle	Secondary oak forest	0,483981032	0,124262132
	Primary deciduous jungle	Secondary oak forest	0,483981032	0,124262132
	Secondary deciduous jungle	Secondary oak forest	0,483981032	0,124262132
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	Primary sub-deciduous jungle	Primary montain mesophilic foresty	1,462335356	0,342578187
	Secondary sub-deciduous jungle	Primary montain mesophilic foresty	1,462335356	0,342578187
	Primary woody xerophylic scrub	Primary montain mesophilic foresty	1,462335356	0,342578187
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	Secondary coniferous forest	Secondary montain mesophilic foresty	0,295151494	0,071960451
	Secondary evergreen jungle	Secondary montain mesophilic foresty	0,295151494	0,071960451
	Primary sub-deciduous jungle	Secondary montain mesophilic foresty	0,295151494	0,071960451
	Primary oak forest	Primary evergreen jungle	0,483704515	0,111601646
	Secondary oak forest	Primary evergreen jungle	0,483704515	0,111601646
	Primary montain mesophilic foresty	Primary evergreen jungle	0,483704515	0,111601646
	Secondary montain mesophilic foresty	Primary evergreen jungle	0,483704515	0,111601646
	Primary sub-deciduous jungle	Primary evergreen jungle	0,483704515	0,111601646

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
Status		Forest land/Reporting subcategory	Ton/C/year	Ton/C/year
	Secondary sub-deciduous jungle	Primary evergreen jungle	0,483704515	0,111601646
	Primary deciduous jungle	Primary evergreen jungle	0,483704515	0,111601646
	Cultived forest	Primary evergreen jungle	0,483704515	0,111601646
	Primary woody hydrophilic vegetation	Primary evergreen jungle	0,483704515	0,111601646
	Special other primary woody types	Primary evergreen jungle	0,483704515	0,111601646
	Special other secondary woody types	Primary evergreen jungle	0,483704515	0,111601646
	Primary coniferous forest	Secondary evergreen jungle	0,626166607	0,140073675
	Primary oak forest	Secondary evergreen jungle	0,626166607	0,140073675
	Primary montain mesophilic foresty	Secondary evergreen jungle	0,626166607	0,140073675
	Secondary montain mesophilic foresty	Secondary evergreen jungle	0,626166607	0,140073675
	Primary sub-deciduous jungle	Secondary evergreen jungle	0,626166607	0,140073675
	Secondary sub-deciduous jungle	Secondary evergreen jungle	0,626166607	0,140073675
	Primary deciduous jungle	Secondary evergreen jungle	0,626166607	0,140073675
	Secondary evergreen jungle	Secondary evergreen jungle	0,626166607	0,140073675
	Primary woody hydrophilic vegetation	Secondary evergreen jungle	0,626166607	0,140073675
	Special other primary woody types	Secondary evergreen jungle	0,626166607	0,140073675
	Primary coniferous forest	Primary sub-deciduous jungle	1,355714996	0,311721643
	Primary oak forest	Primary sub-deciduous jungle	1,355714996	0,311721643
	Secondary oak forest	Primary sub-deciduous jungle	1,355714996	0,311721643
	Secondary montain mesophilic foresty	Primary sub-deciduous jungle	1,355714996	0,311721643
	Primary evergreen jungle	Primary sub-deciduous jungle	1,355714996	0,311721643
	Secondary evergreen jungle	Primary sub-deciduous jungle	1,355714996	0,311721643
	Primary deciduous jungle	Primary sub-deciduous jungle	1,355714996	0,311721643
	Secondary deciduous jungle	Primary sub-deciduous jungle	1,355714996	0,311721643
	Primary woody hydrophilic vegetation	Primary sub-deciduous jungle	1,355714996	0,311721643
	Primary coniferous forest	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary oak forest	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Secondary oak forest	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary montain mesophilic foresty	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Secondary montain mesophilic foresty	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary evergreen jungle	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Secondary evergreen jungle	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary deciduous jungle	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Secondary deciduous jungle	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary woody hydrophilic vegetation	Secondary sub-deciduous jungle	0,634803767	0,147604322
	Primary coniferous forest	Primary deciduous jungle	0,414738123	0,096805142
	Primary oak forest	Primary deciduous jungle	0,414738123	0,096805142
	Secondary oak forest	Primary deciduous jungle	0,414738123	0,096805142
	Primary evergreen jungle	Primary deciduous jungle	0,414738123	0,096805142
	Secondary evergreen jungle	Primary deciduous jungle	0,414738123	0,096805142

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
Status		Forest land/Reporting subcategory	Ton/C/year	Ton/C/year
	Primary sub-deciduous jungle	Primary deciduous jungle	0,414738123	0,096805142
	Secondary sub-deciduous jungle	Primary deciduous jungle	0,414738123	0,096805142
	Primary woody xerophylic scrub	Primary deciduous jungle	0,414738123	0,096805142
	Secondary woody xerophylic scrub	Primary deciduous jungle	0,414738123	0,096805142
	Primary woody hydrophilic vegetation	Primary deciduous jungle	0,414738123	0,096805142
	Secondary woody hydrophilic vegetation	Primary deciduous jungle	0,414738123	0,096805142
	Special other primary woody types	Primary deciduous jungle	0,414738123	0,096805142
	Primary coniferous forest	Secondary deciduous jungle	0,660096078	0,15198938
	Secondary coniferous forest	Secondary deciduous jungle	0,660096078	0,15198938
	Primary oak forest	Secondary deciduous jungle	0,660096078	0,15198938
	Secondary oak forest	Secondary deciduous jungle	0,660096078	0,15198938
	Primary sub-deciduous jungle	Secondary deciduous jungle	0,660096078	0,15198938
	Secondary sub-deciduous jungle	Secondary deciduous jungle	0,660096078	0,15198938
	Primary woody xerophylic scrub	Secondary deciduous jungle	0,660096078	0,15198938
	Secondary woody xerophylic scrub	Secondary deciduous jungle	0,660096078	0,15198938
	Primary woody hydrophilic vegetation	Secondary deciduous jungle	0,660096078	0,15198938
	Secondary woody hydrophilic vegetation	Secondary deciduous jungle	0,660096078	0,15198938
	Special other primary woody types	Secondary deciduous jungle	0,660096078	0,15198938
	Primary coniferous forest	Cultived forest	0	0
	Secondary coniferous forest	Cultived forest	0	0
	Secondary oak forest	Cultived forest	0	0
	Primary evergreen jungle	Cultived forest	0	0
	Secondary evergreen jungle	Cultived forest	0	0
	Primary sub-deciduous jungle	Cultived forest	0	0
	Secondary sub-deciduous jungle	Cultived forest	0	0
	Primary deciduous jungle	Cultived forest	0	0
	Primary coniferous forest	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Secondary coniferous forest	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Primary oak forest	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Secondary oak forest	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Primary deciduous jungle	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Secondary deciduous jungle	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Primary woody hydrophilic vegetation	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Special other primary woody types	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Special other secondary woody types	Primary woody xerophylic scrub	-0,154283518	-0,039431962
	Primary coniferous forest	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Secondary coniferous forest	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Primary oak forest	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Secondary oak forest	Secondary woody xerophylic scrub	0,042228604	0,010153282

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
Status		Forest land/Reporting subcategory	Ton/C/year	Ton/C/year
	Primary deciduous jungle	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Secondary deciduous jungle	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Cultived forest	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Primary woody hydrophilic vegetation	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Secondary woody hydrophilic vegetation	Secondary woody xerophylic scrub	0,042228604	0,010153282
	Primary evergreen jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary evergreen jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary sub-deciduous jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary sub-deciduous jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary deciduous jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary deciduous jungle	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary woody xerophylic scrub	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary woody xerophylic scrub	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Special other primary woody types	Primary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary evergreen jungle	Secondary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary deciduous jungle	Secondary woody hydrophilic vegetation	1,028589094	0,233674469
	Secondary deciduous jungle	Secondary woody hydrophilic vegetation	1,028589094	0,233674469
	Primary sub-deciduous jungle	Special other primary woody types	-0,406353045	-0,104205546
	Secondary sub-deciduous jungle	Special other primary woody types	-0,406353045	-0,104205546
	Primary woody xerophylic scrub	Special other primary woody types	-0,406353045	-0,104205546
	Secondary woody xerophylic scrub	Special other primary woody types	-0,406353045	-0,104205546
	Primary coniferous forest	Special other secondary woody types	0,087234173	0,021375884
	Secondary oak forest	Special other secondary woody types	0,087234173	0,021375884
	Secondary deciduous jungle	Special other secondary woody types	0,087234173	0,021375884
	Primary woody xerophylic scrub	Special other secondary woody types	0,087234173	0,021375884
DEGRADATION	Primary coniferous forest	Secondary coniferous forest	-0,0894	-0,0224
	Primary oak forest	Secondary oak forest	-0,2416	-0,0606
	Primary montain mesophilic foresty	Secondary montain mesophilic foresty	-0,2613	-0,0564
	Primary evergreen jungle	Secondary evergreen jungle	-1,9397	-0,4285
	Primary sub-deciduous jungle	Secondary sub-deciduous jungle	-2,2079	-0,535
	Primary deciduous jungle	Secondary deciduous jungle	-2,2079	-0,535
	Primary woody xerophylic scrub	Secondary woody xerophylic scrub	-0,4656	-0,12
	Primary woody hydrophilic vegetation	Secondary woody hydrophilic vegetation	-1,5772	-0,3643
	Special other primary woody types	Special other secondary woody types	0	0
RECOVERY	Secondary coniferous forest	Primary coniferous forest	0,6242	0,1373
	Secondary oak forest	Primary oak forest	0,6769	0,1636
	Secondary montain mesophilic foresty	Primary montain mesophilic foresty	0,5525	0,1378
	Secondary evergreen jungle	Primary evergreen jungle	1,2141	0,2707
	Secondary sub-deciduous jungle	Primary sub-deciduous jungle	1,7567	0,3888

Forest Lands Remaining as Forest Lands			Factor de emisión / absorción	
	Initial land use	Final land use	Living biomass	Roots
Status		Forest land/Reporting subcategory	Ton/C/year	Ton/C/year
	Secondary deciduous jungle	Primary deciduous jungle	0,8068	0,1847
	Secondary woody xerophylic scrub	Primary woody xerophylic scrub	0,3167	0,254
	Secondary woody hydrophilic vegetation	Primary woody hydrophilic vegetation	0,1158	0,0229

ANNEX 2: GRASSLANDS THAT REMAIN AS GRASSLANDS.

Grasslands that remain as grasslands		Absorption Factor	
Initial land use	Final land use	AF Living Biomass	AF Roots
Grasslands	Grassland/Report subcategory	Ton/C/year	Ton/C/year
Grasslands	Grasslands	0,095402657	0,024845916
Matorral Xerofilo No Lenoso Primario	Primary non- woody xerophylic scrub	0,057014003	0,013007643
Matorral Xerofilo No Lenoso Secundario	Secondary non_woody xerophylic scrub	-0,097288966	-0,024135661
Vegetacion Hidrofila No Lenoso Primario	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Vegetacion Hidrofila No Lenoso Secundario	Secondary non-woody hydrophilic vegetation	0,165366332	0,039074509
Especial Otros Tipos No Lenoso Primario	Special other types non-woody primary	0	0
Matorral Xerofilo No Lenoso Primario	Grasslands	0,095402657	0,024845916
Matorral Xerofilo No Lenoso Secundario	Grasslands	0,095402657	0,024845916
Vegetacion Hidrofila No Lenoso Primario	Grasslands	0,095402657	0,024845916
Especial Otros Tipos No Lenoso Primario	Grasslands	0,095402657	0,024845916
Grasslands	Primary non- woody xerophylic scrub	0,057014003	0,013007643
Matorral Xerofilo No Lenoso Secundario	Primary non- woody xerophylic scrub	0,057014003	0,013007643
Vegetacion Hidrofila No Lenoso Primario	Primary non- woody xerophylic scrub	0,057014003	0,013007643
Especial Otros Tipos No Lenoso Primario	Primary non- woody xerophylic scrub	0,057014003	0,013007643
Grasslands	Secondary non_woody xerophylic scrub	-0,097288966	-0,024135661
Matorral Xerofilo No Lenoso Primario	Secondary non_woody xerophylic scrub	-0,097288966	-0,024135661
Grasslands	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Matorral Xerofilo No Lenoso Primario	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Especial Otros Tipos No Lenoso Primario	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Grasslands	Special other types non-woody primary	0	0
Matorral Xerofilo No Lenoso Primario	Special other types non-woody primary	0	0

ANNEX 3: LANDS CONVERTED TO FOREST LANDS.

Lands converted to forest lands			Absorption Factor	
	Initial land use	Final land use	AF Living Biomass	AF Roots
	Other uses	Tierra forestal/Subcategoria de Reporte	Ton/C/year	Ton/C/year
REFORESTATION	Pastureland	Forest land/reporting subcategory	0,6242	0,1373
	Pastureland	Secondary coniferous forest	0,9575	0,2155
	Pastureland	Primary oak forest	0,6769	0,1636
	Pastureland	Secondary oak forest	0,7297	0,1878
	Pastureland	Primary montain mesophilic foresty	0,5525	0,1378

Pastureland	Secondary montain mesophilic foresty	0,854	0,2096
Pastureland	Primary evergreen jungle	1,2141	0,2707
Pastureland	Secondary evergreen jungle	1,6405	0,3735
Pastureland	Primary sub-deciduous jungle	1,7567	0,3888
Pastureland	Secondary sub-deciduous jungle	1,1777	0,2654
Pastureland	Primary deciduous jungle	0,8068	0,1847
Pastureland	Secondary deciduous jungle	0,6818	0,1583
Pastureland	Cultived forest	0	0
Pastureland	Primary woody xerophylic scrub	0,3167	0,254
Pastureland	Secondary woody xerophylic scrub	0,3167	0,254
Pastureland	Primary woody hydrophilic vegetation	0,1158	0,0229
Pastureland	Secondary woody hydrophilic vegetation	0,1158	0,0229
Pastureland	Special other primary woody types	0,087234173	0,021375884
Pastureland	Special other secondary woody types	0,087234173	0,021375884
Primary non- woody xerophylic scrub	Primary coniferous forest	0,6242	0,1373
Primary non- woody xerophylic scrub	Secondary coniferous forest	0,9575	0,2155
Primary non- woody xerophylic scrub	Primary oak forest	0,6769	0,1636
Primary non- woody xerophylic scrub	Secondary oak forest	0,7297	0,1878
Primary non- woody xerophylic scrub	Special other primary woody types	0,087234173	0,021375884
Primary non- woody xerophylic scrub	Primary deciduous jungle	0,8068	0,1847
Primary non- woody xerophylic scrub	Primary woody xerophylic scrub	0,3167	0,254
Primary non- woody xerophylic scrub	Secondary woody xerophylic scrub	0,3167	0,254
Primary non- woody xerophylic scrub	Primary woody hydrophilic vegetation	0,1158	0,0229
Primary non- woody xerophylic scrub	Special other types non-woody secondary	0,087234173	0,021375884
Secondary non_woody xerophylic scrub	Primary woody xerophylic scrub	0,3167	0,254
Secondary non_woody xerophylic scrub	Secondary woody xerophylic scrub	0,3167	0,254
Secondary non_woody xerophylic scrub	Primary woody hydrophilic vegetation	0,1158	0,0229
Secondary non_woody xerophylic scrub	Special other primary woody types	0,087234173	0,021375884
Primary non-woody hydrophilic vegetation	Primary evergreen jungle	1,2141	0,2707
Primary non-woody hydrophilic vegetation	Secondary evergreen jungle	1,6405	0,3735
Primary non-woody hydrophilic vegetation	Primary sub-deciduous jungle	1,7567	0,3888
Primary non-woody hydrophilic vegetation	Secondary sub-deciduous jungle	1,1777	0,2654

	Primary non-woody hydrophilic vegetation	Primary deciduous jungle	0,8068	0,1847
	Primary non-woody hydrophilic vegetation	Secondary deciduous jungle	0,6818	0,1583
	Primary non-woody hydrophilic vegetation	Primary woody xerophylic scrub	0,3167	0,254
	Primary non-woody hydrophilic vegetation	Secondary woody xerophylic scrub	0,3167	0,254
	Primary non-woody hydrophilic vegetation	Primary woody hydrophilic vegetation	0,1158	0,0229
	Primary non-woody hydrophilic vegetation	Secondary woody hydrophilic vegetation	0,1158	0,0229
	Primary non-woody hydrophilic vegetation	Special other primary woody types	0,087234173	0,021375884
	Primary non-woody hydrophilic vegetation	Special other secondary woody types	0,087234173	0,021375884
	Primary non-woody hydrophilic vegetation	Primary evergreen jungle	1,2141	0,2707
	Primary non-woody hydrophilic vegetation	Secondary deciduous jungle	0,6818	0,1583
	Primary non-woody hydrophilic vegetation	Primary woody hydrophilic vegetation	0,1158	0,0229
	Annual agricultural	Primary coniferous forest	0,6242	0,1373
	Annual agricultural	Secondary coniferous forest	0,9575	0,2155
	Annual agricultural	Primary oak forest	0,6769	0,1636
	Annual agricultural	Secondary oak forest	0,7297	0,1878
	Annual agricultural	Primary montain mesophilic foresty	0,5525	0,1378
	Annual agricultural	Secondary montain mesophilic foresty	0,854	0,2096
	Annual agricultural	Primary evergreen jungle	1,2141	0,2707
	Annual agricultural	Secondary evergreen jungle	1,6405	0,3735
	Annual agricultural	Primary sub-deciduous jungle	1,7567	0,3888
	Annual agricultural	Secondary sub-deciduous jungle	1,1777	0,2654
	Annual agricultural	Primary deciduous jungle	0,8068	0,1847
	Annual agricultural	Secondary deciduous jungle	0,6818	0,1583
	Annual agricultural	Cultived forest	0	0
	Annual agricultural	Primary woody xerophylic scrub	0,3167	0,254
	Annual agricultural	Secondary woody xerophylic scrub	0,3167	0,254
	Annual agricultural	Primary woody hydrophilic vegetation	0,1158	0,0229
	Annual agricultural	Secondary woody hydrophilic vegetation	0,1158	0,0229
	Annual agricultural	Special other primary woody types	0,087234173	0,021375884
	Annual agricultural	Special other secondary woody types	0,087234173	0,021375884
	Permanent agricultural	Primary coniferous forest	0,6242	0,1373
	Permanent agricultural	Secondary coniferous forest	0,9575	0,2155
	Permanent agricultural	Primary oak forest	0,6769	0,1636
	Permanent agricultural	Primary montain mesophilic foresty	0,5525	0,1378
	Permanent agricultural	Secondary montain mesophilic foresty	0,854	0,2096
	Permanent agricultural	Primary evergreen jungle	1,2141	0,2707

	Permanent agricultural	Secondary evergreen jungle	1,6405	0,3735
	Permanent agricultural	Primary sub-deciduous jungle	1,7567	0,3888
	Permanent agricultural	Secondary sub-deciduous jungle	1,1777	0,2654
	Permanent agricultural	Primary deciduous jungle	0,8068	0,1847
	Permanent agricultural	Secondary deciduous jungle	0,6818	0,1583
	Permanent agricultural	Cultived forest	0	0
	Permanent agricultural	Primary woody xerophylic scrub	0,3167	0,254
	Permanent agricultural	Secondary woody xerophylic scrub	0,3167	0,254
	Permanent agricultural	Primary woody hydrophilic vegetation	0,1158	0,0229
	Acuaculture	Primary deciduous jungle	0,8068	0,1847
	Acuaculture	Secondary deciduous jungle	0,6818	0,1583
	Acuaculture	Primary woody hydrophilic vegetation	0,1158	0,0229
	Human settlements	Primary coniferous forest	0,6242	0,1373
	Human settlements	Primary oak forest	0,6769	0,1636
	Human settlements	Secondary oak forest	0,7297	0,1878
	Human settlements	Primary montain mesophilic foresty	0,5525	0,1378
	Human settlements	Primary evergreen jungle	1,2141	0,2707
	Human settlements	Secondary evergreen jungle	1,6405	0,3735
	Human settlements	Primary sub-deciduous jungle	1,7567	0,3888
	Human settlements	Secondary sub-deciduous jungle	1,1777	0,2654
	Human settlements	Primary deciduous jungle	0,8068	0,1847
	Human settlements	Secondary deciduous jungle	0,6818	0,1583
	Human settlements	Primary woody xerophylic scrub	0,3167	0,254
	Human settlements	Secondary woody xerophylic scrub	0,3167	0,254
	Human settlements	Primary woody hydrophilic vegetation	0,1158	0,0229
	Other lands	Primary oak forest	0,6769	0,1636
	Other lands	Secondary oak forest	0,7297	0,1878
	Other lands	Primary evergreen jungle	1,2141	0,2707
	Other lands	Secondary evergreen jungle	1,6405	0,3735
	Other lands	Primary deciduous jungle	0,8068	0,1847
	Other lands	Secondary deciduous jungle	0,6818	0,1583
	Other lands	Cultived forest	0	0
	Other lands	Primary woody xerophylic scrub	0,3167	0,254
	Other lands	Secondary woody xerophylic scrub	0,3167	0,254
	Other lands	Primary woody hydrophilic vegetation	0,1158	0,0229
	Other lands	Secondary woody hydrophilic vegetation	0,1158	0,0229

ANNEX 4: LANDS CONVERTED TO GRASSLANDS.

Lands converted to grasslands		**Absorption Factor**	
Initial land use	**Final land use**	**AF Living Biomass**	**AF Roots**
Grasslands	**Pradera/Reporting subcategory**	**Ton/C/year**	**Ton/C/year**
Annual agricultural	Pastureland	0,3511	0,0908
Annual agricultural	Primary non- woody xerophylic scrub	0,1288	0,0361

Lands converted to grasslands		Absorption Factor	
Initial land use	**Final land use**	**AF Living Biomass**	**AF Roots**
Grasslands	**Pradera/Reporting subcategory**	**Ton/C/year**	**Ton/C/year**
Annual agricultural	Secondary non_woody xerophylic scrub	0,1288	0,0361
Annual agricultural	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Annual agricultural	Special other types non-woody primary	0	0
Permanent agricultural	Pastureland	0,3511	0,0908
Permanent agricultural	Primary non- woody xerophylic scrub	0,1288	0,0361
Permanent agricultural	Secondary non_woody xerophylic scrub	0,1288	0,0361
Permanent agricultural	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Acuaculture	Primary non- woody xerophylic scrub	0,1288	0,0361
Acuaculture	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Human settlements	Pastureland	0,3511	0,0908
Human settlements	Primary non- woody xerophylic scrub	0,1288	0,0361
Human settlements	Secondary non_woody xerophylic scrub	0,165366332	0,039074509
Other lands	Pastureland	0,3511	0,0908
Other lands	Primary non- woody xerophylic scrub	0,1288	0,0361
Other lands	Secondary non_woody xerophylic scrub	0,1288	0,0361
Other lands	Primary non-woody hydrophilic vegetation	0,165366332	0,039074509
Other lands	Special other types non-woody primary	0	0

ANNEX 5: FOREST LANDS REMAINING AS FOREST LANDS.

Forest Lands Remaining as Forest Lands		Emission factor	
Initial land use	**Final land use**	**EF Living Biomass**	**EF Roots**
Forest land	Grassland/Report subcategory	Ton/C/year	Ton/C/year
Primary coniferous forest	Pastureland	-33,62884053	-7,988433947
Primary coniferous forest	Primary non- woody xerophylic scrub	-33,62884053	-7,988433947
Primary coniferous forest	Secondary non_woody xerophylic scrub	-33,62884053	-7,988433947
Secondary coniferous forest	Pastureland	-22,12287576	-5,361795554
Secondary coniferous forest	Primary non- woody xerophylic scrub	-22,12287576	-5,361795554
Secondary coniferous forest	Secondary non_woody xerophylic scrub	-22,12287576	-5,361795554
Primary oak forest	Pastureland	-20,65665182	-5,556745552
Primary oak forest	Primary non- woody xerophylic scrub	-20,65665182	-5,556745552
Secondary oak forest	Pastureland	-14,66697176	-3,994429302
Secondary oak forest	Primary non- woody xerophylic scrub	-14,66697176	-3,994429302
Secondary oak forest	Secondary non_woody xerophylic scrub	-14,66697176	-3,994429302
Secondaryary montain mesophilic foresty	Pastureland	-37,72209997	-9,406692319
Primary montain mesophilic foresty	Pastureland	-18,12549313	-4,678383266
Primary evergreen jungle	Pastureland	-40,38720163	-9,548354646
Primary evergreen jungle	Primary non-woody hydrophilic vegetation	-40,38720163	-9,548354646
Primary evergreen jungle	Special other types non-woody primary	-40,38720163	-9,548354646
Secondary evergreen jungle	Pastureland	-19,65184317	-4,784974308
Secondary evergreen jungle	Primary non-woody hydrophilic vegetation	-19,65184317	-4,784974308

Forest Lands Remaining as Forest Lands		Emission factor	
Initial land use	**Final land use**	**EF Living Biomass**	**EF Roots**
Primary sub-deciduous jungle	Pastureland	-30,23090843	-7,289093064
Primary sub-deciduous jungle	Primary non-woody hydrophilic vegetation	-30,23090843	-7,289093064
Secondary sub-deciduous jungle	Pastureland	-16,06373095	-3,99060589
Secondary sub-deciduous jungle	Primary non-woody hydrophilic vegetation	-16,06373095	-3,99060589
Primary deciduous jungle	Pastureland	-17,39792187	-4,279014377
Primary deciduous jungle	Primary non-woody hydrophilic vegetation	-17,39792187	-4,279014377
Secondary deciduous jungle	Pastureland	-12,64558483	-3,149900523
Secondary deciduous jungle	Primary non-woody hydrophilic vegetation	-12,64558483	-3,149900523
Secondary deciduous jungle	Special other types non-woody primary	-12,64558483	-3,149900523
Cultived forest	Pastureland	0	0
Primary woody xerophylic scrub	Pastureland	-4,256671064	-1,115969319
Primary woody xerophylic scrub	Primary non- woody xerophylic scrub	-4,256671064	-1,115969319
Primary woody xerophylic scrub	Secondary non_woody xerophylic scrub	-4,256671064	-1,115969319
Primary woody xerophylic scrub	Vegetacion Hidrofila No Lenoso Primario	-4,256671064	-1,115969319
Secondary woody xerophylic scrub	Pastureland	-3,162312784	-0,83007519
Secondary woody xerophylic scrub	Primary non- woody xerophylic scrub	-3,162312784	-0,83007519
Secondary woody xerophylic scrub	Secondary non_woody xerophylic scrub	-3,162312784	-0,83007519
Secondary woody xerophylic scrub	Primary non-woody hydrophilic vegetation	-3,162312784	-0,83007519
Primary woody hydrophilic vegetation	Pastureland	-13,2948413	-3,19983932
Primary woody hydrophilic vegetation	Primary non- woody xerophylic scrub	-13,2948413	-3,19983932
Primary woody hydrophilic vegetation	Secondary non_woody xerophylic scrub	-13,2948413	-3,19983932
Primary woody hydrophilic vegetation	Primary non-woody hydrophilic vegetation	-13,2948413	-3,19983932
Primary woody hydrophilic vegetation	Special other types non-woody primary	-13,2948413	-3,19983932
Secondary woody hydrophilic vegetation	Pastureland	-13,2948413	-3,19983932
Secondary woody hydrophilic vegetation	Primary non-woody hydrophilic vegetation	-13,2948413	-3,19983932
Special other primary woody types	Pastureland	-3,458647963	-0,846799108
Special other primary woody types	Primary non- woody xerophylic scrub	-3,458647963	-0,846799108
Special other primary woody types	Secondary non_woody xerophylic scrub	-3,458647963	-0,846799108
Special other primary woody types	Primary non-woody hydrophilic vegetation	-3,458647963	-0,846799108
Special other secondary woody types	Pastureland	-4,61606441	-1,212453159
Special other secondary woody types	Primary non- woody xerophylic scrub	-4,61606441	-1,212453159
Special other secondary woody types	Secondary non_woody xerophylic scrub	-4,61606441	-1,212453159

ANNEX 6: FOREST LAND AND GRASSLAND CONVERTED TO OTHER USES.

Forest Land and Grassland Converted to Other Uses			
Initial Land Use	**Final Land Use**	**EF Living Biomass**	**EF Roots**
Forest/Grassland	**Other usess**	**Ton/C/Year**	**Ton/C/Year**
Primary coniferous forest	Annual agricultural	33,62884053	7,988433947
Primary coniferous forest	Perennial agricultural	33,62884053	7,988433947
Secondary coniferous forest	Annual agricultural	22,12287576	5,361795554
Secondary coniferous forest	Perennial agricultural	22,12287576	5,361795554

Forest Land and Grassland Converted to Other Uses			
Initial Land Use	**Final Land Use**	**EF Living Biomass**	**EF Roots**
Forest/Grassland	**Other usess**	**Ton/C/Year**	**Ton/C/Year**
Primary oak forest	Annual agricultural	20,65665182	5,556745552
Primary oak forest	Perennial agricultural	20,65665182	5,556745552
Secondary oak forest	Annual agricultural	14,66697176	3,994429302
Secondary oak forest	Perennial agricultural	14,66697176	3,994429302
Secondary montain mesophilic forestv	Annual agricultural	37,72209997	9,406692319
Primary montain mesophilic forestv	Perennial agricultural	37,72209997	9,406692319
Primary montain mesophilic forestv	Annual agricultural	18,12549313	4,678383266
Primary evergreen jungle	Annual agricultural	40,38720163	9,548354646
Primary evergreen jungle	Perennial agricultural	40,38720163	9,548354646
Secondary evergreen jungle	Annual agricultural	19,65184317	4,784974308
Secondary evergreen jungle	Perennial agricultural	19,65184317	4,784974308
Primary sub-deciduous jungle	Annual agricultural	30,23090843	7,289093064
Primary sub-deciduous jungle	Perennial agricultural	30,23090843	7,289093064
Secondary sub-deciduous jungle	Annual agricultural	16,06373095	3,99060589
Secondary sub-deciduous jungle	Perennial agricultural	16,06373095	3,99060589
Primary deciduous jungle	Annual agricultural	17,39792187	4,279014377
Primary deciduous jungle	Perennial agricultural	17,39792187	4,279014377
Secondary deciduous jungle	Annual agricultural	12,64558483	3,149900523
Secondary deciduous jungle	Perennial agricultural	12,64558483	3,149900523
Cultived forest	Annual agricultural	0	0
Primary woody xerophylic scrub	Annual agricultural	4,256671064	1,115969319
Primary woody xerophylic scrub	Perennial agricultural	4,256671064	1,115969319
Secondary woody xerophylic scrub	Annual agricultural	3,162312784	0,83007519
Secondary woody xerophylic scrub	Perennial agricultural	3,162312784	0,83007519
Secondary woody xerophylic scrub	Annual agricultural	13,2948413	3,19983932
Primary woody hydrophilic vegetation	Perennial agricultural	13,2948413	3,19983932
Secondary woody hydrophilic vegetation	Annual agricultural	13,2948413	3,19983932
Secondary woody hydrophilic vegetation	Perennial agricultural	13,2948413	3,19983932
Special other primary woody types	Annual agricultural	3,458647963	0,846799108
Special other secondary woody types	Annual agricultural	4,61606441	1,212453159
Special other secondary woody types	Perennial agricultural	4,61606441	1,212453159
Primary sub-deciduous jungle	Acuaculture	17,39792187	4,279014377
Secondary deciduous jungle	Acuaculture	12,64558483	3,149900523
Primary woody xerophylic scrub	Acuaculture	4,256671064	1,115969319
Secondary woody xerophylic scrub	Acuaculture	3,162312784	0,83007519
Primary woody hydrophilic vegetation	Acuaculture	13,2948413	3,19983932
Secondary woody hydrophilic vegetation	Acuaculture	13,2948413	3,19983932
Primary coniferous forest	Human settlements	33,62884053	7,988433947
Secondary coniferous forest	Human settlements	22,12287576	5,361795554
Primary oak forest	Human settlements	20,65665182	5,556745552

Forest Land and Grassland Converted to Other Uses				
	Initial Land Use	**Final Land Use**	**EF Living Biomass**	**EF Roots**
	Forest/Grassland	**Other usess**	**Ton/C/Year**	**Ton/C/Year**
	Secondary oak forest	Human settlements	14,66697176	3,994429302
	Primary montain mesophilic forestv	Human settlements	37,72209997	9,406692319
	Secondary montain mesophilic forestv	Human settlements	18,12549313	4,678383266
	Primary evergreen jungle	Human settlements	40,38720163	9,548354646
	Secondary evergreen jungle	Human settlements	19,65184317	4,784974308
	Primary sub-deciduous jungle	Human settlements	30,23090843	7,289093064
	Secondary sub-deciduous jungle	Human settlements	16,06373095	3,99060589
	Primary sub-deciduous jungle	Human settlements	17,39792187	4,279014377
	Secondary deciduous jungle	Human settlements	12,64558483	3,149900523
	Cultived forest	Human settlements	0	0
	Primary woody xerophylic scrub	Human settlements	4,256671064	1,115969319
	Secondary woody xerophylic scrub	Human settlements	3,162312784	0,83007519
	Primary woody hydrophilic vegetation	Human settlements	13,2948413	3,19983932
	Special other primary woody types	Human settlements	3,458647963	0,846799108
	Secondary woody hydrophilic vegetation	Human settlements	13,2948413	3,19983932
	Special other secondary woody types	Human settlements	4,61606441	1,212453159
	Primary coniferous forest	Other lands	33,62884053	7,988433947
	Primary oak forest	Other lands	20,65665182	5,556745552
	Secondary oak forest	Other lands	14,66697176	3,994429302
	Secondary montain mesophilic forestv	Other lands	18,12549313	4,678383266
	Primary evergreen jungle	Other lands	40,38720163	9,548354646
	Secondary evergreen jungle	Other lands	19,65184317	4,784974308
	Secondary sub-deciduous jungle	Other lands	16,06373095	3,99060589
	Primary sub-deciduous jungle	Other lands	17,39792187	4,279014377
	Secondary deciduous jungle	Other lands	12,64558483	3,149900523
	Primary woody xerophylic scrub	Other lands	4,256671064	1,115969319
	Secondary woody xerophylic scrub	Other lands	3,162312784	0,83007519
	Primary woody hydrophilic vegetation	Other lands	13,2948413	3,19983932
	Secondary woody hydrophilic vegetation	Other lands	13,2948413	3,19983932
Loss of grasslands	Pastureland	Annual agricultural	3,303888647	0,829698843
	Primary non- woody xerophylic scrub	Annual agricultural	0,63630932	0,172627564
	Secondary non_woody xerophylic scrub	Annual agricultural	0,860338495	0,222675627
	Primary non-woody hydrophilic vegetation	Annual agricultural	1,214681813	0,311174368
	Special other types non-woody primary	Annual agricultural	0	0
	Pastureland	Perennial agricultural	3,303888647	0,829698843
	Primary non- woody xerophylic scrub	Perennial agricultural	0,63630932	0,172627564
	Secondary non_woody xerophylic scrub	Perennial agricultural	0,860338495	0,222675627
	Primary non-woody hydrophilic vegetation	Perennial agricultural	1,214681813	0,311174368

Forest Land and Grassland Converted to Other Uses			
Initial Land Use	**Final Land Use**	**EF Living Biomass**	**EF Roots**
Forest/Grassland	**Other usess**	**Ton/C/Year**	**Ton/C/Year**
Special other types non-woody primary	Perennial agricultural	0	0
Pastureland	Acuaculture	3,303888647	0,829698843
Primary non- woody xerophylic scrub	Acuaculture	0,63630932	0,172627564
Secondary non_woody xerophylic scrub	Acuaculture	0,860338495	0,222675627
Primary non-woody hydrophilic vegetation	Acuaculture	1,214681813	0,311174368
Special other types non-woody primary	Acuaculture	0	0
Pastureland	Human settlements	3,303888647	0,829698843
Primary non- woody xerophylic scrub	Human settlements	0,63630932	0,172627564
Secondary non_woody xerophylic scrub	Human settlements	0,860338495	0,222675627
Primary non-woody hydrophilic vegetation	Human settlements	1,214681813	0,311174368
Special other types non-woody primary	Human settlements	0	0
Pastureland	Other lands	3,303888647	0,829698843
Primary non- woody xerophylic scrub	Other lands	0,63630932	0,172627564
Secondary non_woody xerophylic scrub	Other lands	0,860338495	0,222675627
Primary non-woody hydrophilic vegetation	Other lands	1,214681813	0,311174368
Special other types non-woody primary	Other lands	0	0