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Genetic variability of European larch (*Larix decidua* Mill.) in provenance trials established in Romania

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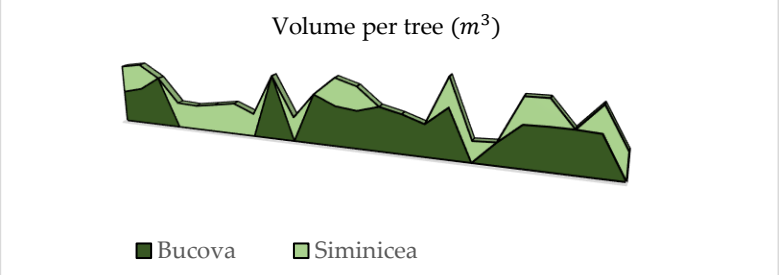
HIGHLIGHTS

- European larch is an important conifer tree species in Romania.
- Large among population genetic variation was observed.
- The study is important to establish appropriate conservation strategies of breeding.

GRAPHICAL ABSTRACT



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ABSTRACT

European larch is one of the most important coniferous species in Romania. It is a fast-growing tree used frequently in reforestations along the Romanian Carpathians. Its natural distribution area in Romania is discontinuous and very limited, representing only 0.3% of the forest area. A series of common garden experiments using European and local larch provenances was established in 1982. The objective of our study was to assess the genetic variability of economic and adaptive traits among European larch provenances, tested in two field trials, to select the best provenances in terms of growth traits, stem straightness, and survival. We also investigated the phenotypic correlations among traits and genotype vs. environment interaction. The analyzed traits included total height, diameter at breast height, volume per tree, pruned height, stem straightness, and survival percentage. The results indicate a large genetic variation within the populations of European larch. The Romanian provenances have a lower growth compared to those from Central Europe but very good stem straightness. The environment factor was significant, therefore the response of the species to climate change will depend on the environmental conditions of the planting site.

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1. INTRODUCTION

The European larch is distributed discontinuously from eastern France to central and south-eastern Italy, and to the mountains of Southern, Central, and Eastern Europe [1]. The Alps are the natural and largest continuous habitat of the European larch. Native stands are located mostly at high altitudes (1000-2900 m), up to the **treeline**, in the Eastern Alps. The best growth is recorded at the altitudes of 1400-1500 m, while at higher altitudes European larch grows less vigorously and faces less competition from other tree species. Larch forests have been estimated to account for around 4% of Europe's total coniferous forest and for less than 1% of the total forest [2]. In Romania, European larch covers around 30,000 ha [3], with the natural distribution area concentrated into five centers: Ceahlău, Ciucaş, Bucegi, Lotru, and Apuseni Mountains**,** totaling approximately 4500 ha.

European larch is a fast-growing species with high-quality wood and high air-pollution resistance. It is particularly shade intolerant compared to other conifers, but it can cope with poor soil and less water availability [4-6]. European larch has double the photosynthesis rates of higher nitrogen levels inside the leaf and a greater leaf area, resulting from less investment in structural tissue and a more carbon-efficient crown shape and canopy structure [7,8].

The European larch, which has a significant level of genetic variation in terms of major economic traits, is one of the most studied forest tree species in Europe. International provenance experiments have identified the best European larch populations regarding growth traits, resistance to diseases and abiotic factors. There is large genetic differentiation within and among local larch populations, which has led to a strong geographic variation in their economic and adaptive traits, as a species with a fragmented distribution [9]. As a result, this genus has been intensively studied since the beginning of the large provenance experiments coordinated by the International Union of Forestry Research Organizations (IUFRO). In 1944, R. Schober organized the first international experiment on this species, followed, in 1958, by further studies [10,11]. In Romania, European larch breeding program started in 1978 and 1982 by establishing two series of common garden experiments through international collaboration (six geographic locations), using Romanian and foreign larch provenances [12]. Afterwards, 26 seed orchards (134 ha) have been established in Romania of which three (15 ha) are of interspecific hybridization (*Larix* x *eurolepis*), and more than 300 plus trees have been grafted [13].

Despite the economic importance of European larch for some populations of *sudetica* and *polonica* varieties [4-6,11,14] and alpine and Romanian Carpathians larch [15], genetic variation of the traits has also been highlighted. The findings showed that, among the European larch progeny from the same provenance, there were significant differences in their growth characteristics, adaptability and wood quality [16-19]. Genetic variability has also been found in resistance to canker disease (*Lachnellula willkommii*), which is harmful in European larch. The European larch has shown significant genetic variation throughout the species range related to sensitivity to drought [20].

Knowledge of the geographical genetic variation of the European larch populations in Romania is becoming increasingly important in the context of climate change, in order to establish

the appropriate strategies for the conservation of forest genetic resources, improve species adaptability to climate change, and continue the European larch breeding program [17,18].

The objective of this study was to investigate 1) genetic variability of the economic and adaptive traits among European larch provenances tested in field trials, 2) phenotypic correlations among traits and 3) genotype-environment interaction, in order to select the best provenances, in terms of growth traits, stem straightness and adaptive capacity, as valuable germplasm sources for reforestation and breeding programs.

2. MATERIALS AND METHODS

The material for this study consisted of 16 European larch provenances - seven Romanian and nine foreign, from Germany (three), Austria (two), Belgium (one), and Slovakia (three) (**Table 1**). The provenances tested originated from seed orchards, plantations, and natural stands. Out of the total number, eight provenances are common in both trials: 30 (Harbker, Hanau 11, seed orchard) and 31 (Hanau 11, seed orchard) from Germany; 54, 55 (Bicaz, artificial stand), 59 (Sinaia, artificial stand) and 62 (Brașov, artificial stand) from Romania; and 63 (Zilina-Hradok), 65 (Keimarok-Lubica) from Slovakia [21]. Romanian provenances come from five natural populations (native to the Romanian Carpathians), five artificial stands of unknown origin, and two seed orchards. The Furnicoși seed orchard is an interspecific hybridization (*Larix decidua* x *L. leptolepis*) seed orchard and plus trees of European larch originated from Brașov, Sinaia, and Latorița forest districts (Curvature and Southern Carpathians). Plus, trees tested in Hemeiuși seed orchard come from the Eastern Carpathians and Apuseni Mountains.

The provenance trials analyzed in this study were established in 1982 in two locations - Bucova (southwest of the country) and Siminicea (northeast of the country). The experimental design consisted of square grids comprising 4 × 4 provenances, with 25 trees per plot and three repetitions. Both experimental trials were established outside the larch's natural distribution area in Romania, in the mountain European beech and oak layer, respectively. The site conditions and location of field trials are presented in **Table 2**.

In each trial, 10 trees from the category of dominant or codominant were measured in each plot and each of the three repetitions. The traits analyzed were categorized as follows: growth traits - total height (m), diameter at breast height (cm), volume per tree (m^3); wood quality traits - pruned height (m), stem straightness (index), and adaptive traits - survival (%). The stem straightness was evaluated using an index, where 1 = straight stem, 2 = minor defects, and 3 = sinuous stem. Tree diameter measurements were made using a caliper at a height of 1.30 m from the ground. The measurement of tree height is very important for determining the volume and other shape parameters. A Vertex III was used for this, following well-established procedures. The observations and measurements of these characteristics were made in 2021, at age 39.

Microsoft Office Excel and SPSS software were used to process the data from field measurements. Data analysis was done by simple and multifactorial analysis of variance with the following sources of variation: provenance, repetition, locality, and the interaction between them.

Table 1. Provenances of *Larix decidua*

No.	Code	Provenance	Country	Lat. N	Long. E	Altit.
1	30	Harbker, Hanau 11 – seed orchard	Germany	-	-	-
2	31	Hanau 11 – seed orchard	Germany	-	-	-
3	32	West Sudd. Mittelgeb Berkel – seed orchard	Germany	-	-	-
4	33	Reichenau / Kärnten	Austria	46°51′	13°58′	1550
5	35	Wienerwald-Lammerau-seed orchard	Austria	-	-	-
6	45	Haldensleben Oberforsterei Bischofswald	Germany	52°20′	11°15′	105
7	47	Halle – seed orchard	Belgium	-	-	-
8	50	Reghin – artificial stand	Romania	46°40′	24°50′	450
9	51	Mihăeşti, Furnicoşi - seed orchard	Romania	-	-	-
10	52	Bacău, Hemeiuși I – seed orchard	Romania	-	-	-
11	53	Bacău, Hemeiuşi II - seed orchard	Romania	-	-	-
12	54	Bicaz – artificial stand	Romania	46°49′	25°52′	1100
13	55	Bicaz – natural stand	Romania	46°57′	25°58′	1500
14	56	Baia de Criş – natural stand	Romania	46°25′	23°30′	1100
15	57	Comăneşti – artificial stand	Romania	46°15′	26°12′	710
16	58	Latoriţa – natural stand	Romania	45°12′	23°55′	1100
17	59	Sinaia – artificial stand	Romania	45°15′	25°30′	690
18	60	Sinaia – natural stand	Romania	45°20′	25°30′	1600
19	61	Sinaia – natural stand	Romania	45°10′	25°40′	1300
20	62	Braşov – artificial stand	Romania	45°30′	25°30′	670
21	63	Zilina - Hradok	Slovakia	49°00′	19°56′	650
22	64	Poprad-Hranovnica	Slovakia	48°59′	20°11′	900
23	65	Keimarok - Lubica	Slovakia	49°07′	20°28′	720
24	66	Presov	Slovakia	49°00′	21°06′	550

Table 2. Location and site conditions of larch provenances trials established in 1982

No.	Trial name Forest District P.U., m.u.*	Region of Prov.	Mean annual temperature (^{0}C)	Total annual precip. (mm)	Lat. N	Long. E	Altit.	Vegetation layer	Soil type
1.	Bauțar Bauțar U.P. VIII, u.a. 1A	D2	2.55	1030	45°29′	22°40′	650	Mountain European beech	brown forest soil
2.	Siminicea Fălticeni U.P. VI, u.a 45 C	G1	5.42	594	47°30′	26°20′	350	Mixture of oak species	brown forest soil

The statistical analysis was based on the individual tree measurements using the following mathematical model [22]:

$$Y_{kil} = \mu + P_k + R_i + L_l + e_{ikl} \quad (1)$$

where Y_{kil} = performance of the k^{th} provenance in the i^{th} repetition and l^{th} locality; μ = overall mean; P_k = effect of the k^{th} provenance; R_i = effect of the i^{th} repetition; L_l = effect of the l^{th} locality and e_{kil} = random error associated with the kil^{th} trees. Pearson's correlations based on provenance means were also calculated to examine phenotypic correlations and relationships between traits.

3. RESULTS

3.1. Genetic Variability

The analysis of variance for each site revealed significant statistical differences among the European larch provenances tested in the 1982 series in terms of growth characteristics (**Table 3**). The provenance factor significantly influenced all characters studied in the Bucova trial, while only for height (total and pruned) and stem straightness in the Siminicea trial.

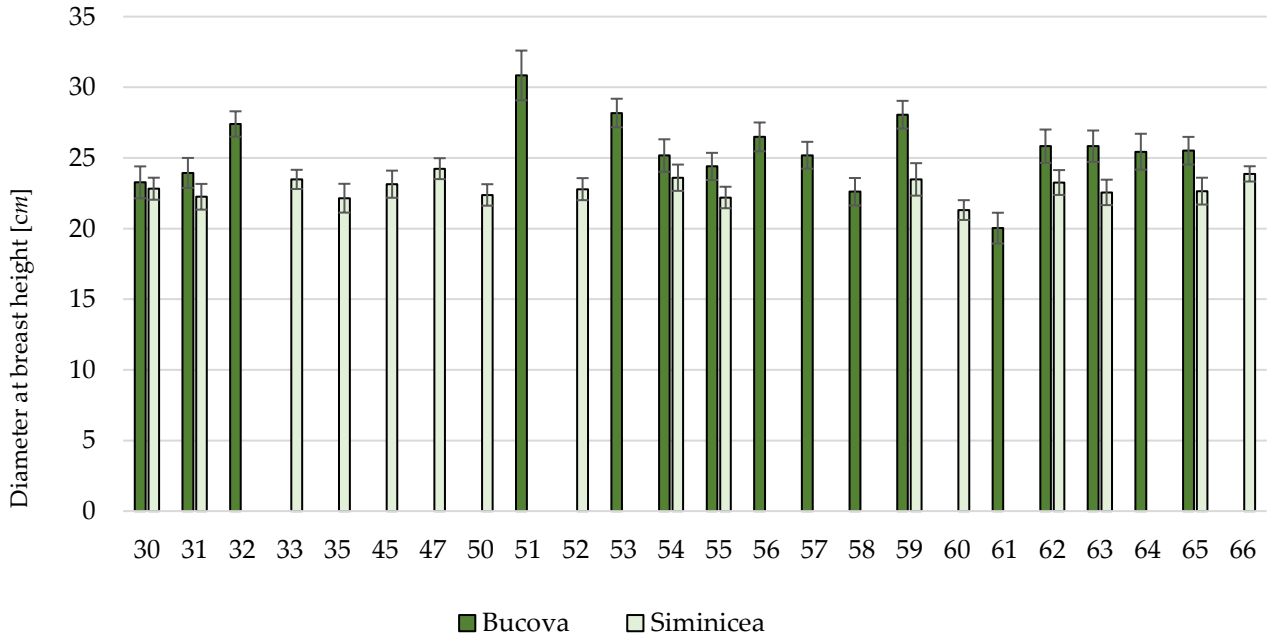
Table 3. Analysis of variance for studied traits in the European larch provenance trials at age 39

Source of variation	S^2						
	D.F	Volume/tree	DBH	Total height	Pruned height	Stem straightness	Survival
Siminicea field trial							
Provenances	15	0.040	16.144	22.257***	33.652***	0.888***	254.99
Repetitions	2	0.095	16.134	133.103	394.280	0.613	1335.44
Error	30	0.030	19.187	4.668	4.498	0.284	1335.44
Bucova field trial							
Provenances	15	0.521**	148.267***	38.236***	12.509***	1.892***	134.733*
Repetitions	2	0.034	13.262	12.496	13.781	1.507	22.333
Error	30	0.107	34.387	5.548	2.987	0.573	22.333

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

The largest diameters at breast height were obtained in the Bucova trial ($\bar{x}$=25.5 cm). The best performing provenances in this trial were: 51 (Mihăeşti, Furnicoşi, seed orchard), Romania; 53 (Bacău, Hemeiuşi II, seed orchard), Romania; 59 (Sinaia, artificial stand), Romania; and 32 (West Sudd. Mittelgeb Berkel, seed orchard), Germany. In the Siminicea trial, the mean on the experiment was $\bar{x}$=22.9 cm and the best provenances were: 47 (Halle, seed orchard), Belgium; 66 (Presov),

Slovakia; 54 (Bicaz, artificial stand), Romania; 33 (Reichenau, Kärnten), Austria; and 45 (Haldensleben), Germany (**Figure 1**). The lowest values for diameter at breast height were registered by the provenances: 61 (Sinaia, artificial stand), Romania in the Bucova trial, and 60 (Sinaia, natural stand) also Romania in the Siminicea trial.



whiskers [*error bar*] represent standard error [*SE*]

Figure 1. Variation of the diameter at breast high in provenance trials

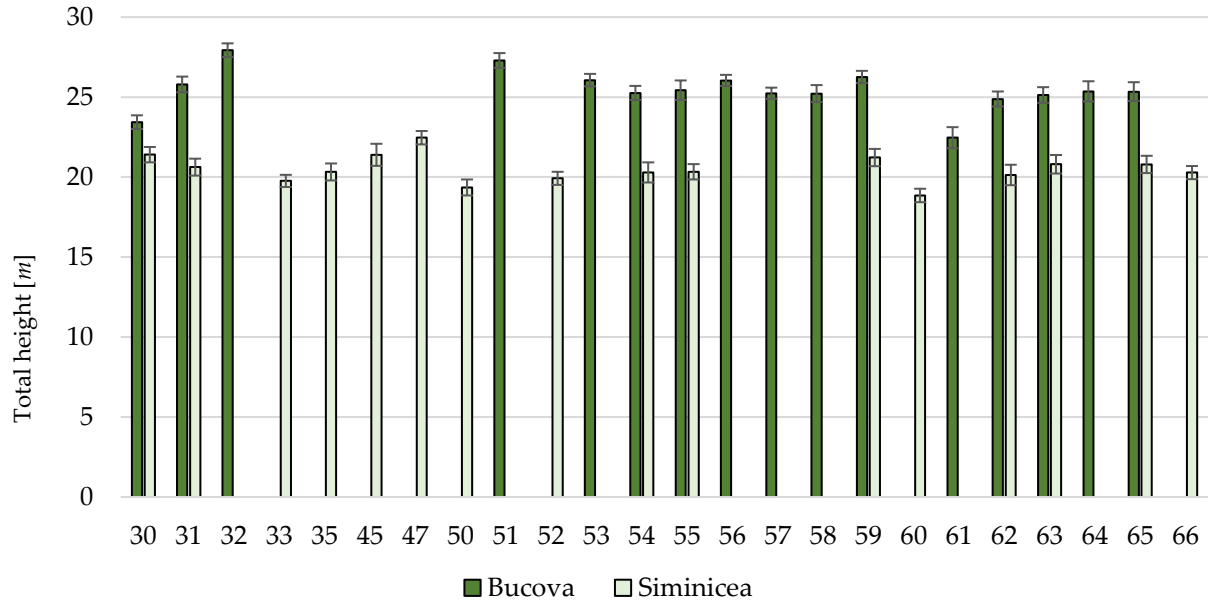


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Figure 2. Variation of total height in provenance trials

The highest total heights (**Figure 2**) have been recorded in the Bucova trial ($\bar{x}$ =25.5 m) by the following provenances: 32 (Berkel, seed orchard, Germany), 51 (Mihăeşti, Furnicoşi, seed orchard, Romania), 53 (Bacău, Hemeiuşi II, seed orchard, Romania), 59 (Sinaia, artificial stand, Romania) and 56 (Baia de Criş, natural stand, Romania). In the Siminicea trial ($\bar{x}$=20.5 m) the provenances with the highest values of total heights were: 47 (Halle, seed orchard, Belgium), 30 (Harbker, Hanau 11, seed orchard, Germany), 45 (Haldensleben Oberforsterei Bischofswald, Germany) and 59 (Sinaia, artificial stand, Romania). The lowest values for the total heights were obtained by the provenances 60 (Sinaia, natural stand, Romania at the Siminicea trial) and 61 (Sinaia, artificial stand, Romania at Bucova trial).

The greatest volume per tree (**Figure 3**) was recorded in the Bucova trial, where the mean of the experiment was $\bar{x}$=0.65 m^3, compared to Siminicea trial where the mean of the experiment was $\bar{x}$=0.41 m^3. In the Bucova trial, the best provenances in terms of volume per tree were: 51 (Mihăeşti, Furnicoşi, seed orchard), Romania; 32 (Berkel, seed orchard), Germany; 59 (Sinaia, artificial stand), Romania; 53 (Bacău, Hemeiuşi II, seed orchard), Romania; and 56 (Baia de Criş, natural stand), Romania. The lowest volumes per tree in this trial were recorded: 61 (Sinaia, natural stand), Romania; 58 (Latoriţa, natural stand), Romania and 30 (Harbker, Hanau 11, seed orchard), Germany. In the Siminicea trial, the following provenances recorded the highest volumes per tree: 47 (Halle, seed orchard), Belgium; 59 (Sinaia, artificial stand), Romania; 45 (Haldensleben Oberforsterei Bischofswald), Germany; and 54 (Bicaz, artificial stand), Romania. The lowest values have obtained: 60 (Sinaia, natural stand), Romania; 55 (Bicaz, natural stand), Romania; and 50 (Reghin, artificial stand), Romania.

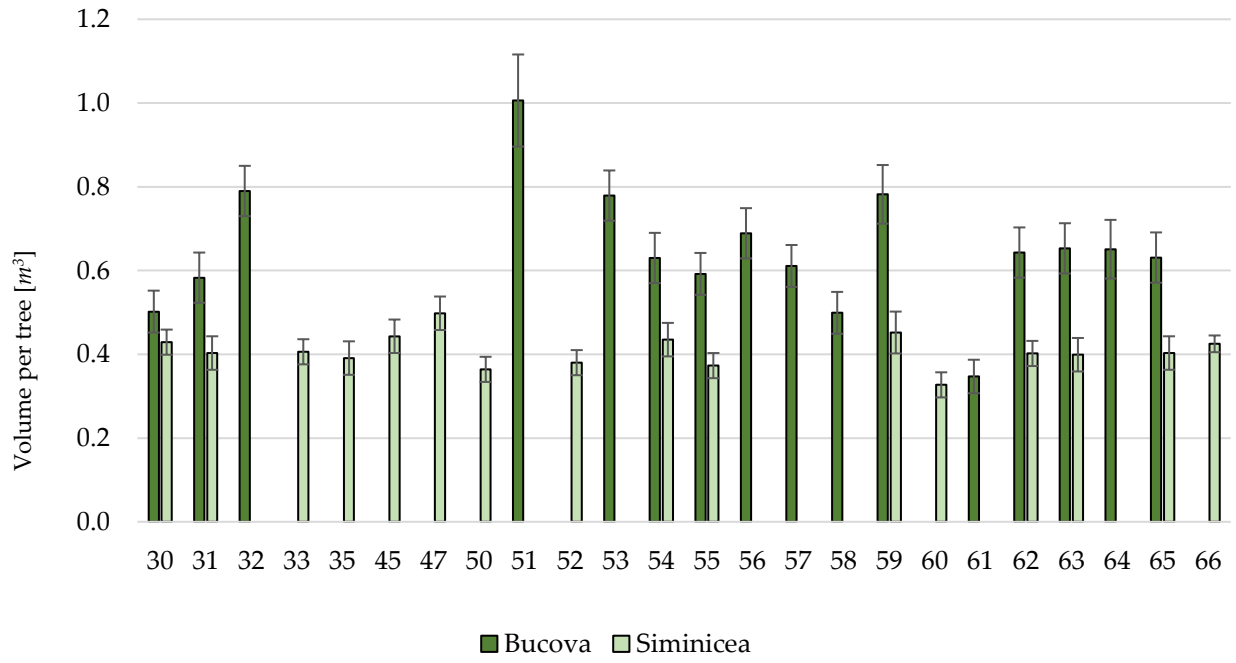

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Figure 3. Variation of the volume per tree

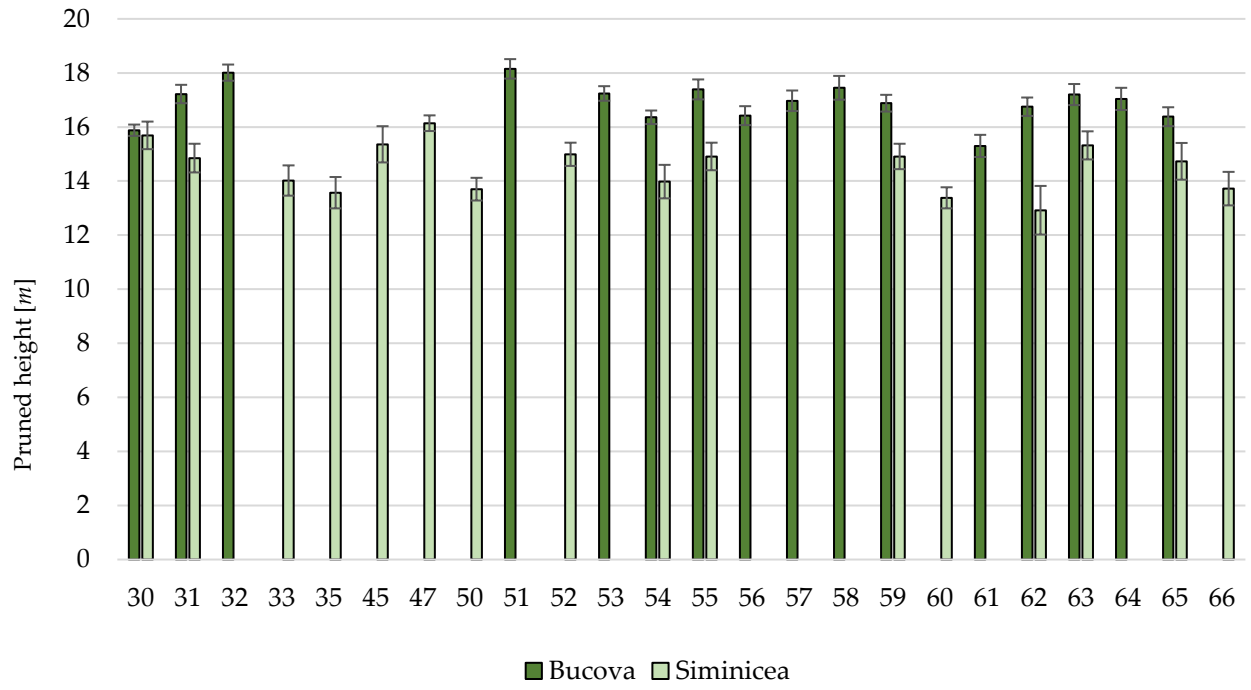

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Figure 3. Variation of pruned height in the provenance trials

The highest value for pruned height (**Figure 4**) has been recorded in the Bucova trial by provenance 51 (Mihăeşti, Furnicoşi, seed orchard), Romania. In Siminicea trial, the highest pruned height was obtained by provenance 59 (Sinaia, artificial stand, Romania). The lowest values were registered by the provenances 60 (Sinaia, natural stand, Romania) and 61 (Sinaia, artificial stand, Romania).

The most defects in the stem shape were observed in the Bucova trial ($\bar{x}$=1.73), with lesser amounts recorded in the Siminicea trial ($\bar{x}$=1.45), but with only a slight difference (**Figure 5**). In Bucova trial, the provenances with the most stem defects were: 56 (Baia de Criş, natural stand, Romania), 55 (Bicaz, natural stand, Romania) and 54 (Bicaz, artificial stand, Romania), 64 (Poprad, Hranovnica, Slovakia), while in the Siminicea trial were: 50 (Reghin, artificial stand, Romania) and 59 (Sinaia, artificial stand, Romania) and 66 (Presov, Slovakia). The fewest defects were recorded by 61 (Sinaia, natural stand, Romania) and 58 (Latoriţa, natural stand, Romania) at Bucova trial and 54 (Bicaz, artificial stand, Romania), 62 (Braşov, artificial stand, Romania) and 60 (Sinaia, natural stand, Romania) at Siminicea trial.

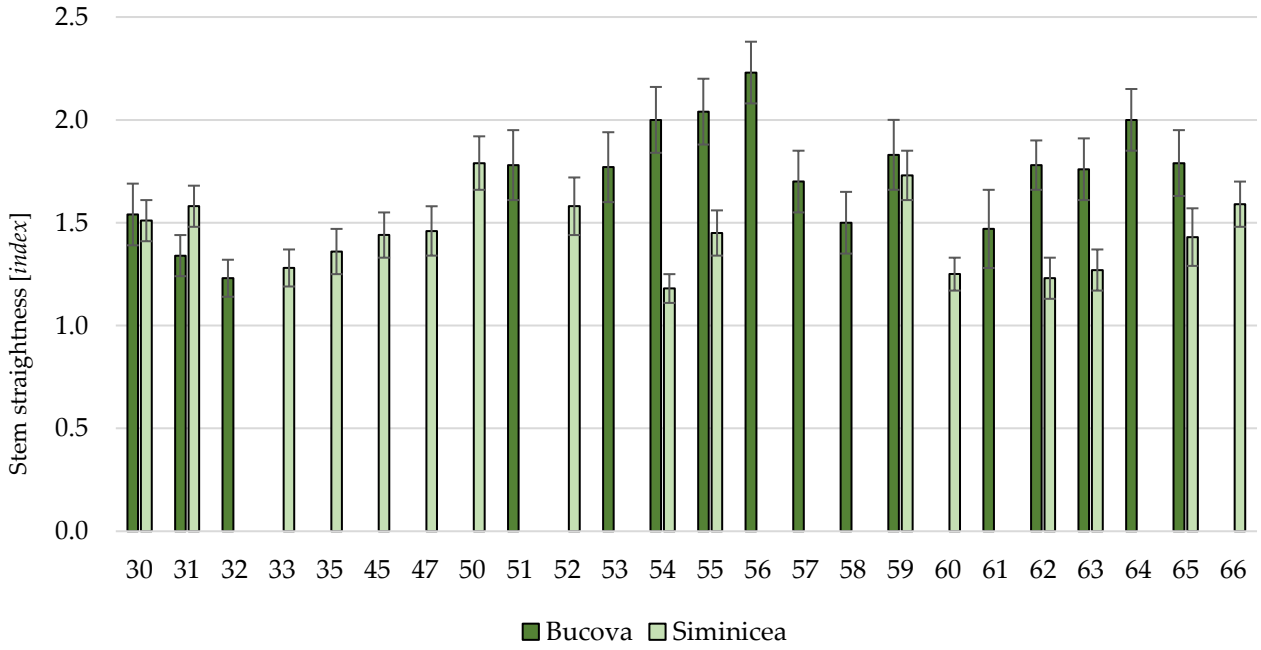

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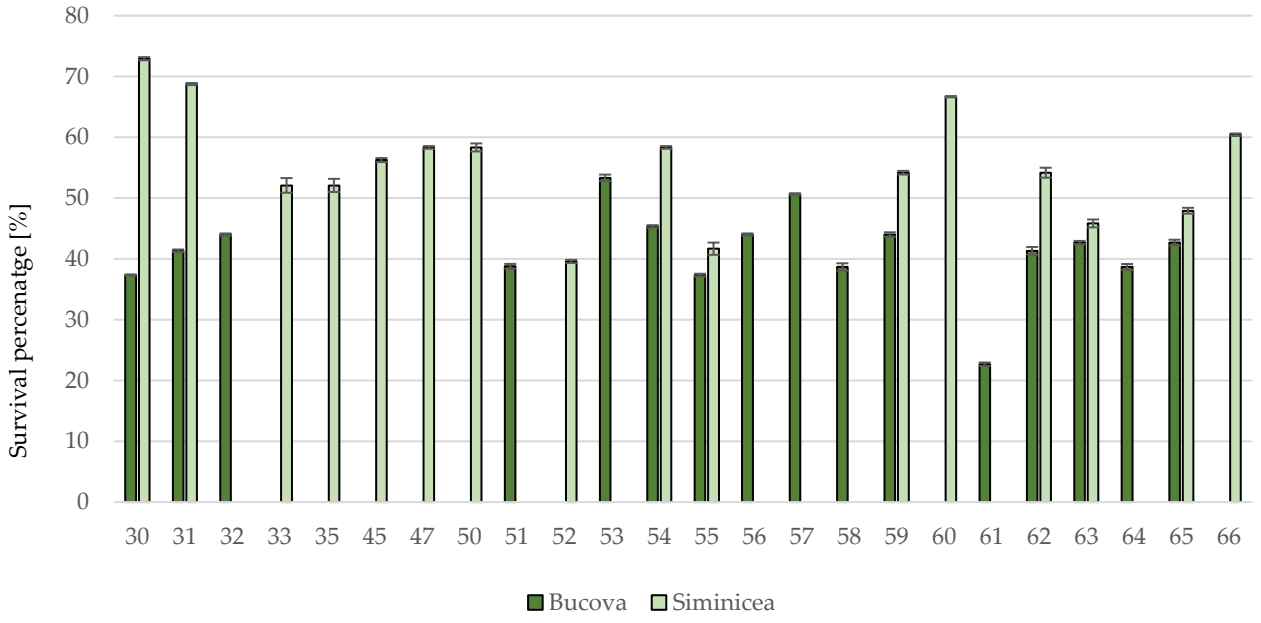
Figure 5. Variation of stem straightness in the provenance trials



whiskers [*error bar*] represent standard error [*SE*]

Figure 6. Variation of stem straightness in the provenance trials

At age 39, the survival rate varied considerably among the experimental trials and provenances. The highest percentage of survival was recorded at Siminicea ($\bar{x}$=55%) and the lowest at Bucova ($\bar{x}$=41%) (**Figure 6**). The provenances with the highest survival percentage in the Bucova trial were: 53 (Bacău, Hemeiuşi II, seed orchard, Romania), 54 (Bicaz, artificial stand, Romania), and 57 (Comăneşti, artificial stand, Romania). At Siminicea trial, the best adaptability was recorded by 30 (Harbker, Hanau 11, seed orchard, Germany), 31 (Hanau 11, seed orchard, Germany), and 60

(Sinaia, natural stand, Romania). The lowest survival percentage was recorded in provenances 30 (Harbker, Hanau 11, seed orchard, Germany), 55 (Bicaz, natural stand, Romania), and 61 (Sinaia, natural stand, Romania) at the Bucova trial, while at the Simincea trial, the lowest survival was found at the provenances 63 (Zilina-Hradok, Slovakia), 55 (Bicaz, natural stand, Romania) and 52 (Bacău, Hemeiuşi I, seed orchard, Romania).

3.2. Phenotypic Correlations Between Traits

Phenotypic correlations among studied traits are presented in **Tables 4** and **5**. Analyzing both filed trials, it can be observed that more significant correlations have been obtained in Bucova trial compared to Siminicea trial.

Table 4. Pearson correlations of traits in Bucova trial, 2021

Variable	Pruned height	DBH	Volume/tree	Stem straightness	Survival rate
Total height	0.844***	0.824***	0.860***	0.042	0.577*
Pruned height		0.644***	0.703**	-0.119	0.416
Diameter at 1.30 m			0.989***	0.287	0.603*
Volume per tree				0.219	0.527*
Stem straightness					0.216

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

Table 5. Pearson correlations of traits in Siminicea trial, 2021

Variable	Pruned height	DBH	Volume/tree	Stem straightness	Survival rate
Total height	0.793***	0.563*	0.881***	0.143	0.077
Pruned height		0.247	0.562*	0.263	-0.049
Diameter at 1.30 m			0.854*	0.056	-0.025
Volume per tree				0.104	0.142
Stem straightness					0.084

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

In both trials, positive significant correlations were obtained between growth traits and pruned height. Also, in Bucova trial there are positive significant correlations between survival rate and total height, diameter at the breast height, and volume per tree, respectively (**Table 4**). In the Siminicea trial, no significant correlations were obtained between growth traits and survival (**Table 5**). No correlations have been obtained in the provenance trials between growth traits and stem straightness.

3.3 Provenance - environment interaction

At age 39, the analysis of variance across sites did not indicate a significant statistical influence of the provenance factor for the studied traits (**Table 6**). The site conditions strongly

influenced the variation of all studied traits. The interaction between provenance and site conditions was not significant for growth traits, wood quality, and survival rate.

Table 6. Analysis of variance for studied traits in the two provenance trials at age 39

Source of variation	s^2						
	D.F.	Volume/ tree	DBH	Total height	Pruned height	Stem straightness	Survival
Provenance (P)	7	0.011	4.909	1.828	2.780	0.079	178.330
Location (L)	1	0.556***	55.922***	277.152***	82.268**	1.245**	2341.512**
Interaction P x L	7	0.009	2.568	1.951	3.374	0.168	203.628
Error	32	0.009	3.611	4.340	6.006	0.109	172.190

4. DISCUSSION

The studied material included 16 European larch provenances, originating from three categories of genetic resources: natural populations, artificial stands, and seed orchards, which cover a large part of the geographical distribution of species in Central and Eastern Europe. A high level of genetic variability for growth traits, stem straightness, and survival rate at the provenance level was observed in each site. Across sites, the provenance factor was not significant and the environment factor had the greatest influence. These findings suggest that environmental conditions can exert a variety of impacts on European larch characteristics, particularly in the context of climate change. The lack of significance of provenance-environment interaction indicates high spatial stability in terms of growth and adaptive performance of the European larch provenances.

The best growth performances were recorded in Bucova trial located in the southwest of the country, in the European beech mountain layer at 650 m altitude, in a mild climate with Mediterranean influences. Siminicea trial is located in the Moldova Plateau (northeast of the country), in the sessile oak layer at 350 m altitude, in a continental climate. In the last 30 years, the Moldova Plateau was one of the most affected regions by climate change, in Romania. In this region, the mean annual temperature has increased by 1.02 °C in the last three decades [16] and the total annual precipitation is very low (594 mm), being below the vegetation optimum for *Quercus robur*. As opposed to Siminicea site conditions, at Bucova the mean annual temperature has increased by 0.45 °C in the last three decades and the total annual precipitation is around 1030 mm, being situated in optimal climatic conditions for European beech.

At age 39, in both trials, the highest volumes per tree were recorded by 2 seed orchards: 51 (Mihăeşti, Furnicoşi, seed orchard, Romania at Bucova trial) and 47 (Halle, seed orchard, Belgium at Siminicea trial). At the Bucova trial, volumes above mean on experiment have obtained also Berkel seed orchard from Germany, Hemeiuși seed orchard from Romania, 63-Zilina-Hradok and 64-Poprad from the Tatra Mountains, and the Romanian provenances 59-Sinaia (artificial stand) and 56-Baia de Criș (natural stand). At the Siminicea trial, the Romanian seed orchard (52-Hemeiuși) and natural populations are placed at the end of the ranking of growth traits. In this trial site, the highest wood production has obtained the following provenances: 59 (Sinaia, artificial stand) and 54 (Bicaz,

artificial stand) from Romania, and 45 (Haldensleben Oberforsterei Bischofswald) and 30 (Harbker, Hanau 11, seed orchard) from Germany.

Comparing the provenances ranking for the growth traits at this age with those previously obtained at age 25 [15] a high similarity could be seen for the Siminicea trial, while at the Bucova trial some changes in the provenances standing have occurred. Thus, if at the 25 years old all Romanian natural populations (except 61 - Sinaia) and seed orchards have been situated above the experimental mean, at present all natural populations (except 56 from Apuseni Mountains) have dropped below the mean. The seed orchards: 51-Furnicoşi and 53-Hemeiuşi from Romania and 32-Berkel from Germany, have maintained their position within ranking emphasizing a high growth and adaptive capacity.

Selection for the most productive provenances would bring significant genetic gains in timber production. Generally, fast-growing provenances have the highest mortality rates. Our results highlighted a positive significant correlation between growth traits and survival, in the Bucova trial. The provenances that combine both high wood production and survival rate are 53 (Hemeiuşi, seed orchard), 56 (Bicaz, natural stand), 59 (Sinaia, artificial stand) Romania; 63 (Zilina-Hradok, 650-m), Slovakia, and 32 (Berkel, seed orchard), Germany.

The good growth performances of the provenances 59-Sinaia and 54-Bicaz, artificial stands of unknown origin, could be explained by their non-local origin, most likely from the Tyrolean Alps [19,23]. Results from IUFRO experiments have demonstrated that the provenances from the south-eastern Alps had moderate growth and good adaptability [10,24]. The Romanian provenances have a lower growth compared to those from Central Europe but very good stem straightness.

5. CONCLUSIONS

Our findings indicate a large within-population genetic variation in European larch. Substantial genetic variability was also observed for the quantitative traits (volume per tree, diameter at breast height, total height, and pruned height) among the European larch provenances in each field trial. The environmental factor was also significant. Consequently, the response of this species to climate change will depend on the environmental conditions of the planting site and also on the provenance. Generally, the seed orchards have obtained the best growth, stem shape, and adaptability, which demonstrates the genetic improvement of this forest reproductive material, as result a of phenotypic selection at the population and plus trees level. However, the genetic composition of the seed orchards is important as the best growth and additive performances have been recorded by 51-Furnicoşi and 53-Hemeiuși, Romania; 32-Berkel and 30-Harbker, Germany, and 47-Halle, Belgium, respectively. Provenance trials represent forest genetic resources that can provide important information about the intraspecific genetic variation, the most valuable seed sources, and the adaptive genetic potential of species in the context of climate change. These genetic resources should be maintained and managed in a sustainable manner. Further efforts to conserve genetic resources of European larch should lead to an integrated conservation strategy, considering both *ex-situ* and *in-situ* approaches.

SUPPLEMENTARY MATERIALS

Not the case.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

APPENDIX

Not the case.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu: *Variabilitatea genetică a laricelui (Larix decidua MILL.) în culturi de proveniențe instalate în România.*

Introducere: *Laricele are un areal discontinuu din estul Franței spre centrul și sudul - estul Italiei, munții din sudul, centrul și estul Europei. Alpii sunt cel mai mare habitat natural și continuu al laricelui. Se estimează că pădurile de larice european reprezintă aproximativ 4% din totalul pădurilor de conifere și mai puțin de 1% din totalul pădurilor din Europa. În Romania, laricele vegetează spontan în cinci centre montane Ceahlău, Ciucaş, Bucegi, Lotru și Apuseni. Laricele este o specie cu creștere rapidă, cu lemn de înaltă calitate și rezistență ridicată la poluarea aerului. Această specie are un nivel ridicat de variabilitate genetică pentru caracteristicile economice majore, fiind una dintre cele mai studiate specii din Europa. Laricele este o specie forestieră importantă în România, iar programul său de ameliorare genetică a început în anii 1960. Obiectivul principal al acestui program a fost de a îmbunătăți rezistența la factorii biotici și de mediu, și de a crește producția și calitatea lemnului. Cunoașterea variației genetice geografice a populațiilor de larice devine din ce în ce mai importantă în contextul schimbărilor climatice, pentru stabilirea unor strategii adecvate de conservare a resurselor genetice forestiere, pentru a îmbunătăți adaptabilitatea speciei la schimbările climatice și pentru a continua programul de ameliorare genetică în România. Obiectivele acestui studiu au fost de a evalua variabilitatea genetică la nivelul proveniențelor de larice testate în culturi experimentale, de a studia corelațiile dintre caractere și de a investiga interacțiunea genotip - mediu, cu scopul selecției celor mai bune proveniențe, în ceea ce privește caracterele de creștere, formă a fusului şi supraviețuirea, ca surse valoroase de germoplasmă pentru programele de reîmpădurire și ameliorare.*

***Materiale şi metode**: Materialul acestui studiu constă din 16 proveniențe de larice, 7 românești și 9 străine, din următoarele țări: Germania (3), Austria (2), Belgia (1) și Slovacia (3). Proveniențele 30, 31, 54, 55, 59, 62, 63, 65 sunt comune în ambele culturi. Materialul testat provine din plantaje de larice, arborete artificiale și arborete naturale. Culturile cu proveniențe de larice analizate în acest studiu au fost instalate în anul 1982, în două locații (Bucova și Siminicea), iar dispozitivul experimental este grilaj pătrat de tip 4 × 4 cu 3 repetiții. În fiecare cultură au fost măsurați 10 arbori (din categoria dominant sau codominant) pe parcela unitară, în fiecare dintre cele 3 repetiții. Măsurătorile în suprafețele experimentale au fost efectuate la vârsta de 39 de ani, iar metoda de evaluare în teren a constat în măsurători biometrice și observații cu privire la înălțimea totală, diametrul la 1.30 m, volumul mediu pe arbore, înălțimea elagată, forma fusului și supraviețuirea. Programele Excel și SPSS au fost utilizate pentru prelucrarea şi analiza statistică a datelor și a observațiilor din teren.*

***Rezultate şi discuții:** Analiza variației în fiecare loc de testare a evidențiat diferențe statistice semnificative între proveniențele de larice testate, în ceea ce privește caracterele analizate. Cele mai mari valori pentru diametrul la 1,30 m au fost obținute în cultura comparativă Bucova. În cultura Bucova, cele mai mari creșteri în diametru au înregistrat proveniențele : 51 - Furnicoşi (plantaj, România), 53 - Hemeiuși II (plantaj, România), 59 - Sinaia (arboret artificial, România) şi 32 - Berkel (plantaj, Germania). Cele mai mari valori pentru înălțimea totală au fost înregistrate, de asemenea, în cultura Bucova, iar în topul clasamentului au fost situate proveniențele : 32 - Berkel (plantaj, Germania), 51 - Furnicoşi (plantaj, Romania) și 59 - Sinaia (arboret artificial, Romania). În cultura comparativă Siminicea, proveniențele care au obținut cele mai mari valori ale înălțimii totale au fost : 47 - Halle (plantaj, Belgia), 30 - Harbker, Hanau (plantaj, Germania) și 45 - Haldensleben Oberforsterei Bischofswald (Germania). În cultura comparativă Bucova s-au înregistrat cele mai bune rezultate în ceea ce privește volumul mediu pe arbore, în topul clasamentului situându-se plantajul 51 - Furnicoși, România, în timp ce în cultura comparativă Siminicea în topul clasamentului se situează plantajul 47 - Halle, Belgia. De asemenea, în cultura comparativă Bucova s-au înregistrat cele mai mari înălțimi elagate, dar şi cele mai multe defecte de formă ale fusului. În ambele locuri de testare, cea mai bună formă a fusului o prezintă proveniențele din Romania și Austria. Cele mai mari procente de supraviețuire, la vârsta de 39 de ani de la plantare au fost înregistrate în cultura comparativă Siminicea (55%), iar cele mai reduse în cultura comparativă Bucova (41%). Proveniențele cu cea mai bună supraviețuire în ambele locuri de testare sunt: 54 - Bicaz și 59 - Sinaia (arborete artificiale). Corelații pozitive semnificative între caracterele de creștere şi supraviețuire au fost obținute doar în cultura comparativă Bucova. Interacțiunea proveniență - localitate a fost nesemnificativă pentru caracterele de creștere, de calitate a lemnului și supraviețuire, sugerând o stabilitate spațială mare a performanțelor proveniențelor de larice. Analiza multifactorială a variației, evidențiază o influență mai mare a condițiilor staționale comparativ cu factorul proveniență pentru caracterele studiate.*

***Concluzii:** Rezultatele acestui studiu indică o variabilitate genetică ridicată la nivelul proveniențelor de larice în ambele culturi comparative. Performanțele proveniențelor de larice sunt influențate, în primul rând, de condițiile staționale ale locului de testare. Cele mai bune performanțe de creștere au fost obținute în cultura comparativă Bucova, situată în etajul făgetelor montane, într-un climat mai blând cu influențe mediteraneene. În general, plantajele au obținut cea mai bună creștere, formă a fusului și adaptabilitate, fapt care dovedește superioritatea materialului obținut prin ameliorare, ca urmare a selecției fenotipice la nivel de populații și arbori plus. Cu toate acestea, compoziția genetică a plantajelor contează, prin urmare, cele mai bune performanțe de creștere şi adaptare au înregistrat plantajele: 51-Furnicoşi şi 53-Hemeiusi, România, 32-Berkel și 30-Harbker, Germania și 47-Halle, Belgia.*

***Cuvinte cheie:** larice, variabilitate genetică, resurse genetice forestiere, provenanțe, corelații fenotipice.*

REFERENCES

1.Praciak, A., & C.A.B. International, 2013: The CABI encyclopedia of forest trees. Wallingford, Oxfordshire, UK: Cabi.

2. NFI, 2018: National Forest Inventory, http://roifn.ro/site/rezultate-ifn-2/. (Accessed on June 2021).

3. Şofletea N., Curtu L., 2001: Dendrologie, Editura pentru viata, p 300.

4. Schober R., 1949: Larch: an investigation of growth, yield and biology.

5. Mayer H., 1977: Die Lärche (Larix decidua [europaea] Mill.). Forest construction on socio-economic basis - ecological basis. Stuttgart, New York, p 22–28.

6. Englisch M., Starlinger F., Lin H., 2011: Die Lärche—ein Baum für alle Fälle? BFW-Praxis Information, No.25 – 2011.

7. Matyssek R., 1986: Carbon, water and nitrogen relations in evergreen and deciduous conifers. Tree physiology, 2(1_2_3), p 177–187. https://doi.org/10.1093/treephys/2.1-2-3.177.

8. Gower, S. T., & Richards, J. H.,1990: Larches: Deciduous Conifers in an Evergreen World. BioScience, 40(11), p 818–826. https://doi.org/10.2307/1311484.

9. Matras, J., Pãques, L.E., 2008: European larch (Larix decidua). EUFORGEN Technical Guidelines for Genetic Conservation and Use, p 6. ISBN: 978-92-9043-788-8.

10. Giertych M., 1979: Summary of results on European larch (Larix decidua Miller) height growth in the IUFRO 1944 provenance experiment.

11. Weisgerber H., Sindelar J., 1992: IUFRO's role in coniferous tree improvement. History, results, and future trends of research and international cooperation with European larch (Larix decidua Mill.), Silvae Genetica 41(3), p 150 - 160.

12. Violeta E., 1972: Plantaje pentru producerea semințelor genetic ameliorate de specii valoroase și repede crescătoare, Seria a II – a, p 142.

13. Violeta E., 1984: Cercetări de proveniență la duglas și larice, Seria a II – a, p 144.

14. Frýdl J., Šindelář J., 2002: Some genetic characteristics of European larch (Larix decidua Mill.) on the base of progeny from a diallel crossing evaluation at the age of 31 years. In: Final report 'Towards a European Larch Wood Chain' EU project 98-3354, Task3, p 21 – 40.

15. Mihai, G., Teodosiu, M. 2009. Genetic diversity and breeding of larch (Larix decidua Mill.) in Romania. Annals of Forest Research 52(1): p 97-108.

16. Mihai G., 2021. Technical rapport of the project PN 303: Revision of the provenances regions for production and deployment of the forest reproductive materials in Romania in order to increase the adaptability of forest ecosystems to climate change from Nucleu Programme. Manuscript, p 40.

17. Šindelář J., 1992: Genetics and improvement of European larch (Larix decidua Mill.), Annales Forestales 18(1), p 1 – 36.

18. Gracan J., 1973: Heritability of certain characters of the Varazdinbreg population of Larix decidua, Sumarski List 97(9/10), p 358 – 374.

19. Mihai G., Alexandru A., Mirancea I., 2019: Genetic variation and early selection in Larix decidua Mill. from progeny test in Romania. Annals of Forest Science 76:81.

20. George J.P., Grabner M., Karanitsch-Ackerl S., Mayer K., Weißenbacher L., Schueler S., et al. 2017: Genetic variation, phenotypic stability, and repeatability of drought response in European larch throughout 50 years in a common garden experiment, Tree Physiol., 37, p 33–46.

21. Mihai G., 2009: Surse de semințe testate pentru principalele specii de arbori forestieri din românia, Editura silvică, p 20.

22. Nanson A., 2004: Genetic and forest trees breeding. Ed. Gembloux, Belgium (In French), p 712.

23. Raffl H., Konrad H., Curtu L.A., Geburek T., 2018: Genetic evidence of human mediated, historical seed transfer from the Tyrolean Alps to the Romanian Carpathians in Larix decidua (Mill.) forests. Ann For Sci 75, p 98.

24. Lacaze J-F., Birot Y.,1974: Results of a provenance trial of European Larch after 13 years. Ann Sci For 31(3), p 135–159.

25. http://www.euforgen.org (Accessed on 15. 09. 2021).

26. http://www.esf.edu (Accessed on 22.10.2021).

27. http://www.forestgeneticsbc.ca (Accessed on 8.08.2021).

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STATE OF THE ECUADORIAN FORESTS AND THEIR CONTRIBUTION TO THE GROSS DOMESTIC PRODUCT

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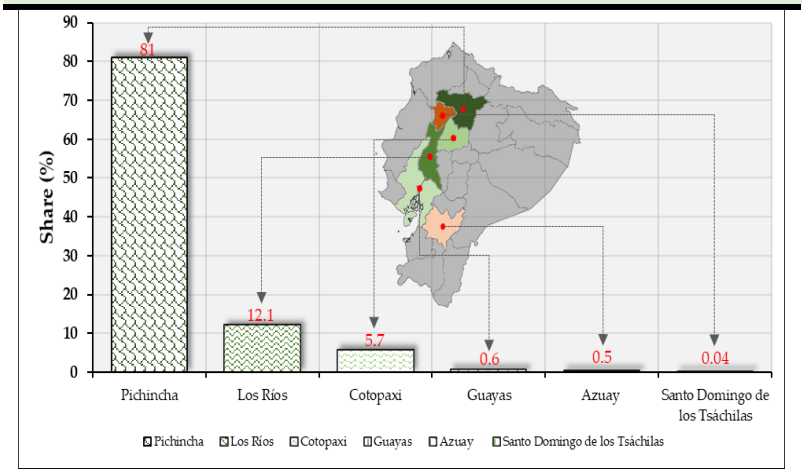
HIGHLIGHTS

- Ecuador, is one of the 12 countries of South America, which is considered one of the megadiverse countries around the world, with an area of 256,370 km².
- In Ecuador there are currently 204 companies dedicated to forestry and wood extraction.
- Ecuador has a forest cover on more than half of its territory, with large areas suitable for forestry use.

GRAPHICAL ABSTRACT



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ABSTRACT

Forest ecosystems have always been an important source of provision of goods and services for humankind, that have facilitated its existence. Based on a bibliographic review, an analysis was carried out on the forest cover and use in Ecuador, as well as on how this sector contributes to the country's economy in terms of employment generation and Gross Domestic Product (GDP). The results of this study can be useful to understand the importance of the forestry sector that has been gradually generating contributions to the country's economy from a perspective of new sources of employment and progress, cover and use of forest land. The knowledge acquired could be useful to support the development of strategies and decision-making for the public, private and community sectors according to the exclusive and concurrent competencies of each institution.

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1. INTRODUCTION

Forests constitute one of the main capitals for environmental, social and economic development [1]. From an environmental point of view, they provide a wide range of ecosystem services and promote climate change mitigation [2]. From a social perspective, they provide non-material aspects such as community relations and trust, culture and spirituality [3]. In addition, they are considered an important source of food, firewood, construction material and medicinal products [4]. The production and use of timber resources is expanding globally; in 2015, global productive forest plantations amounted to 109 million hectares (ha), increasing at a rate of 2.0 million hectares per year during the period 2010 and 2015 [5]. Forest plantations increasingly supply wood fibers for the energy industry; the traditional forestry industry [6], and possible future uses include the production of increasingly challenging forestry production [7]. In 2019, economic activity in the forestry sector, including forestry, forest management, timber, pulp and paper, accounted for 1% of GDP in Europe and North America, and 0.8% in Russia [8]. According to Li et al. [9], during 2018 it was estimated that 58 of 111 countries represented 70% of the world's total forest surface, contributed 92% of world's GDP and produced 93% of the world total of industrial roundwood, 93% of sawn wood and veneer logs, 94% sawn lumber, 97% wood-based panels, 99% wood pulp, and 98% paper and board.

Forests from Latin America represent one of the most important natural resources [10]. 18% of the total forest surface is found in protected areas, while 14% of the total area fulfills productive functions [11]. The forestry sector of Latin America provides a range of goods and services that enable the subsistence of various populations; this plays an important role in local and national processes [12]. In recent years, more than 11 million hectares of plantations have been established in Latin America. 70% of these are in Brazil (5.4 million ha); other leading countries are Chile (2.7 million ha), Argentina (1.2 million ha), Uruguay (0.8 million ha), Venezuela (0.8 million ha) and Ecuador (0.2 million ha) [5]. Ecuador, which is one of the 12 countries of South America, is considered one of the megadiverse countries, with an area of 256,370 km² [13]. Its great variation in physical and climatic conditions has allowed the formation of four well-defined natural regions: Coast, Highlands, Amazon and the insular region of the Galapagos Islands [14-16]. It is estimated that there are more than 1,250 plant species/km², belonging to 136 different families with high levels of endemism [17-19]. According to the studies by the Food and Agriculture Organization of the United Nations (FAO) [20], 40% of the national territory is covered with natural forests (the majority in the Amazon), and 1% with forest plantations; in addition, 45% of the country's total area is suitable for forest use [21]. Most of these lands are part of territories belonging to communities, ancestral peoples and protected areas [22]. There are 750 forest species that are exploited annually: 48% for obtaining non-timber forest products (NTFPs), 45% for timber forest products (PFM) and 7% for firewood [11]. In recent years, Ecuador has been characterized as a country with an extractive economy that depends on raw material exports [23]. Exports of raw material have been gradually increasing; in 1990 an export value of USD 28 million was recorded, during 2019 it increased to USD 304.1 million dollars from wood (1.4% of total exports), which is equivalent to 637,000 metric tons [20]. Currently, in the country there is a high potential for forest production [24], while the wood is exported mainly to countries such as United States, Colombia, Venezuela, Peru and Mexico, among others [25]. In recent years, Ecuadorian wood has had a better performance since there are greater

exports of different kinds of wood and its products; although it has not exceeded the levels of trade abroad, the growth in this sector has been overwhelming [26]. Currently there are sales of raw wood and those that have had a primary transformation of industrialization, such as plywood, chipboard and medium-density fiberboard or MDF, among other wood products [25].

The economic contributions of the forestry sector for a given country are evaluated under two economic indicators: employment and added value [9]. Employment is represented by the annual average of job vacancies, according to The World Bank [27]. The formal timber sector employs more than 13.2 million people in direct or indirect jobs and contributes significantly to income generation for small farmers globally [28]. Value added measures the contribution to the Gross Domestic Product (GDP), which represents the total value of a country's goods and services [29]. The World Bank [30], registered a GDP of 6.9% per year concerning the activities of agriculture, forestry production and fishing worldwide. In this context, in the period from 2009 to 2018, an average GDP of 1.3% was identified as a result of forestry activity in Ecuador [31], generating a total of 324,000 jobs [32]. The country has shown in recent years a gradual growth of the sector, therefore, it is important to continuously evaluate macroeconomic information, so that it can be used in favor of successful planning to meet market demands and effective decision-making in the public, private and community sectors. Analyzing these indicators is one of the greatest challenges for the forestry sector at the national level, since eventually there is a high share of illegal deforestation generated by various items without registration, resulting in misguided analyses.

Given the importance of forestry in the current context, this study analyzes the integration of macroeconomic perspectives in relation to forestry production in Ecuador. Therefore, the objectives of this work were: *i)* to identify the classification of forest land use at the national level and *ii)* to analyze the contribution to the economy of Ecuador in terms of employment generation and the contribution of the forestry sector to the country's GDP through a retrospective analysis.

2. MATERIALS AND METHODS

The study was implemented by a systematic literature review on the macroeconomic perspectives in relation to forestry production in Ecuador. The specific objectives addressed the cover and use of forest land, and the analysis of the GDP of the forestry sector in the country by a review of official documents of government entities of Ecuador (Survey of continuous agricultural production surface - ESPAC, Ministry of the Environment of Ecuador - MAE, Internal Revenue Service - SRI and Superintendency of Companies). Additionally, recent scientific articles from national and international databases were reviewed, with the aim of being able to carry out a more comprehensive analysis for the study. The subject was approached from an interdisciplinary perspective, and predetermined keywords were used for both cases. The extracted information incorporated several aspects. First, in relation to forests in Ecuador, this study focused on three topics: *i*) land occupation by category in continental Ecuador by region, *ii*) stratification of occupation and land use of forests, and *iii*) deforestation with a retrospective analysis in the period of 2000-2016. Subsequently, a review of aspects related to the macroeconomic analysis of the forestry situation was carried out, focusing in the same way on three axes: *i*) national timber market based on local sales of forestry and timber extraction in the period 2006-2019, *ii*) foreign market for wood

from exports Incoterm Free On Board (FOB) of the forestry sector 2016-2021, and the main exporting companies of Ecuador, and, *iii*) the forestry sector and its role in the macroeconomy through a retrospective analysis of GDP 2016-2020, and the generation of employment in the forestry sector. The information obtained included a common database that allowed making a series of necessary interpretations in this research. Consequently, this study provides metrics with a large number of variables.

3. RESULTS AND DISCUSSION

3.1. Forests of Ecuador

3.1.1. Forest Land Cover

Land use refers to the use of land in the rural sector of the country [33]. **Table 1** shows the land use surface of Ecuador by classification category.

Table 1. Surface, according to category of land use in Ecuador. Adapted from [34]

N°	Land Use	Surface (ha)	(%)	% Variation compared to previous year
1	**Permanent Crops**	1,439,117	11.6	0.2
2	**Transitory Crops and Fallow**	849,685	6.9	6.9
3	**Without Intervention**	125,946	1.0	-2.0
4	**Cultivated Pastures**	2,300,539	18.6	4.1
5	**Natural Pastures**	800,496	6.5	-4.9
6	**Paramo**	377,791	3.1	-8.0
7	**Mountains and Forests**	5,773,290	46.8	1.2
8	**Other uses**	719,109	5.8	2.9
	Total	**12,385,973**	**100**	**1.3**

In 2019, according to ESPAC [35], the total national area was almost 12.5 million hectares, presenting a growth of 1.3% compared to the total area of the previous year. The largest area of land use is devoted to mountainous forests, which represent 46.8% of the national total, followed by cultivated pastures, which occupy 18.6%, and permanent crops, 11.6%.

Table 2. Surface of land use categories by region in Ecuador. Adapted from [34]

Region	Area (ha)	(%)	Land use							
			Permanent Crops	Transitory Crops and Fallow	Without Intervention	Cultivated Pastures	Natural Pastures	Paramo	Mountains and Forests	Other uses
Coast	**4,829,876**	39.0	1,076815	555,622	65,384	1,291,397	120,280	4,996	1,367,316	348,066
Highlands	**3,789,505**	30.6	229,670	266,269	54,824	640,993	594,615	361,994	1,467,340	173,801
Amazon	**3,748,196**	30.3	122,398	27,635	5,732	366,063	85,512	10,802	2,933,671	196,384
Undefined areas	**18,395**	0.1	10,234	159	6	2,087	88	-	4,963	858
Total	**12,385,973**	**100**	**1,439,117**	**849,685**	**125,946**	**2,300,539**	**800,495**	**377,791**	**5,773,290**	**719,109**

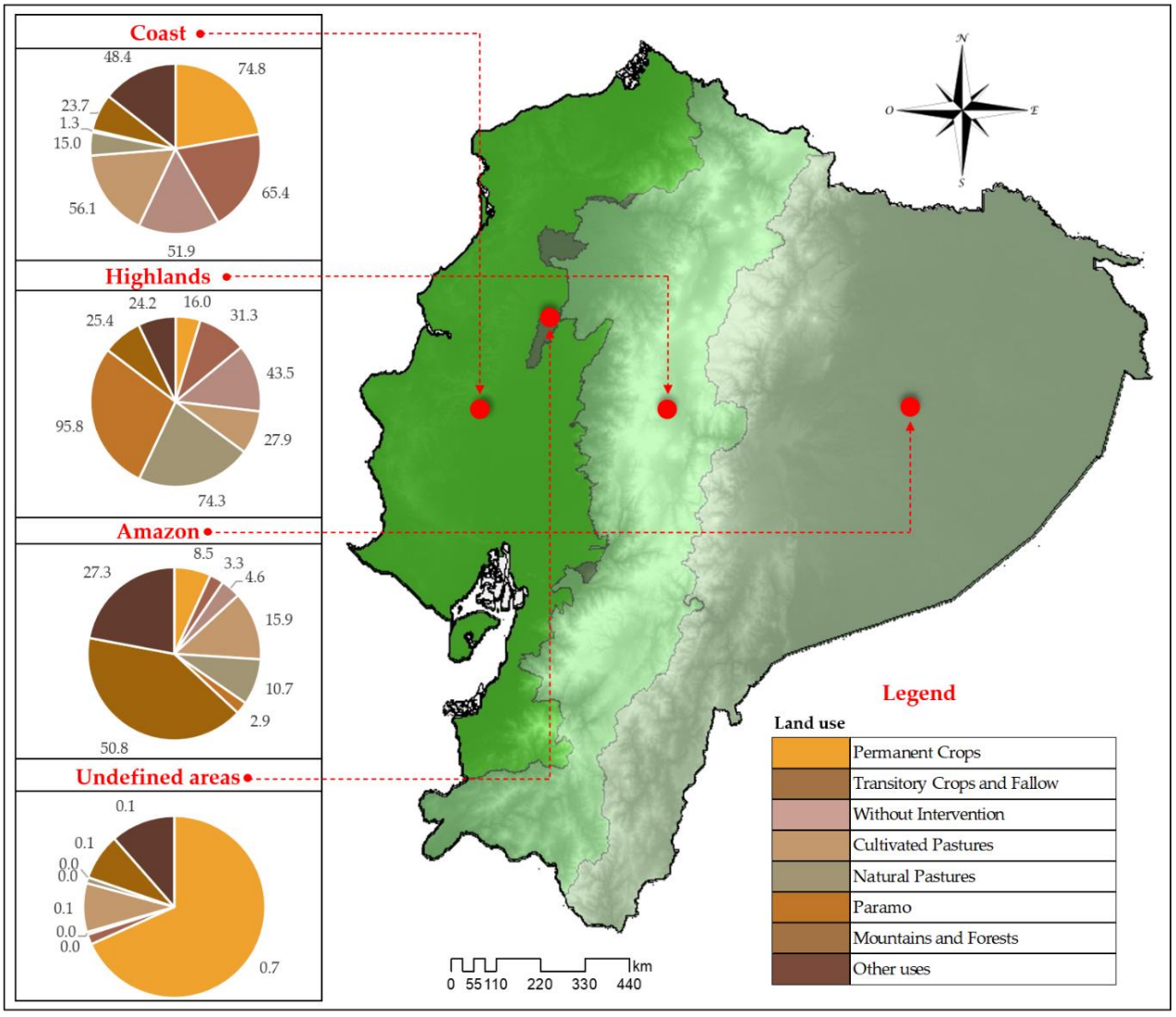

Figure 1. Share of the surface of the categories of land use by region of Ecuador

The Ecuadorian continental territory is divided into three regions, namely Coast, Highlands and Amazon, which are determined by environmental factors such as the presence of the Andes Mountain range, the vegetation of the Amazon and the currents of El Niño and Humboldt [36]. **Table 2** and **Figure 1** show the area by region according to the type of land use in Ecuador. In 2016, the total area by region was 12,385,973 hectares, being divided in 38.8% on the Coast, 30.4% in Highlands, 30.1% in Amazon and 0.8% in undefined areas. In the Coast region, the use of land is mainly for permanent crops (74.8%), followed by transitory crops and fallow (65.4%); the rest (51.9%) is used for cultivated pastures (56.1%) and other uses (48.4%). In the Highlands region, the largest area of land use is covered by moors (95.8%) and natural pastures (74.3%). Finally, in the Amazon region predominates the land covered by mountains and forests (50.8%).

3.1.2. Forest Use in Ecuador

The natural forest is the formation of trees, shrubs and other plant species, primary or secondary, regenerated by natural succession [37], and is characterized by the presence of trees of different native species, varied ages and sizes, with one or more strata [38]. **Table 3** and **Figure 2** show the area of the stratification of the natural forests of Ecuador according to MAE [39].

Table 3. Stratification of the forests of continental Ecuador. Adapted from [39]

No	Stratum	Area (ha)	Number of trees per hectare		Basal area (m^2/ha)	Trading volume (m^3/ha)	Carbon average (T/ha)
			> 20 cm	< 20 cm			
1	Amazon Lowland Evergreen Forest	6,665,893	196	359	26.6	239.7	160.4
2	Andean Montane Evergreen Forest	1,998,052	146	418	20.0	126.3	123.1
3	Andean Evergreen Forest of Pie de Monte	1,247,816	176	360	24.5	205.3	122.8
4	Evergreen Forest of the Choco Lowlands	888,841	131	289	18.2	145.6	83.3
5	Dry pluvioseasonal forest	679,264	56	177	9.1	53.9	37.0
6	Evergreen Andean Forest of Ceja Andina	528,212	124	550	14.7	69.4	105.1
7	Moretals	430,803	241	171	30.0	288.0	75.8
8	Andean dry forest	161,910	69	259	11.0	61.3	47.9
9	Mangrove swamp	152,595	94	232	11.1	136.3	86.6
	Total	**12,753,387**					

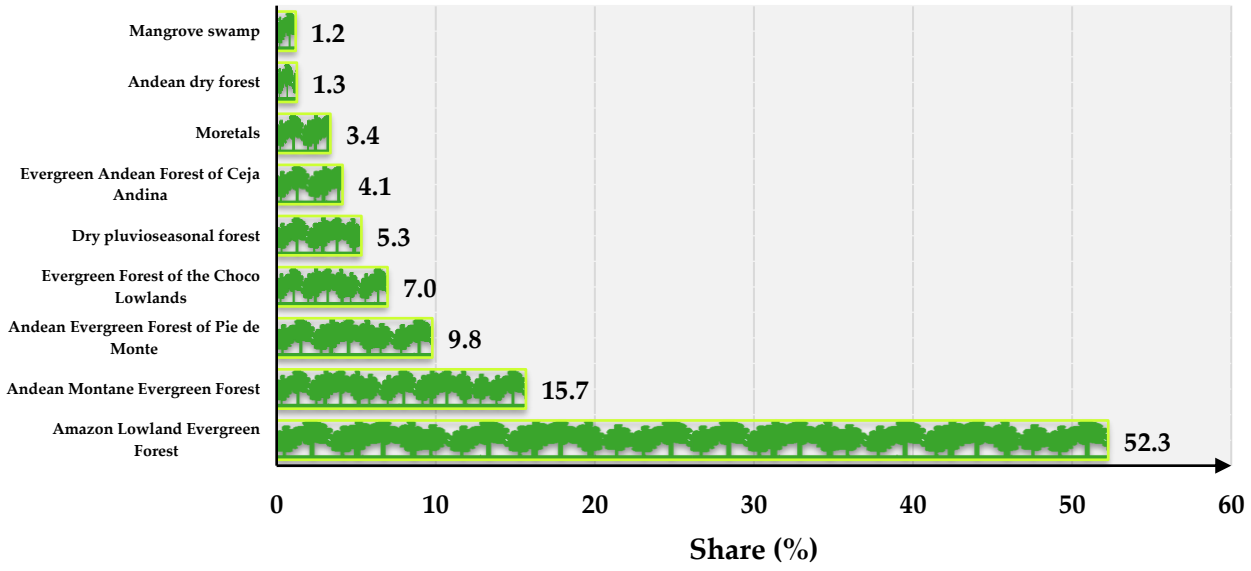

Figure 2. Surface of natural forest stratification in continental Ecuador. Adapted from [39]

The total continental area was 12,753,387 million of hectares. The largest surface area of the natural forest stratification is allocated to the Evergreen Lowland Forest of Amazon, which represents 52.3%, followed by the Evergreen Andean Montane Forest, which occupies 15.7%, and the Evergreen Andean Pie de Monte Forest, which accounts for 9.8%. The stratification of the natural Mangrove Forest represents the smallest extension of the continental territory with 1.2%.

3.1.3. Deforestation in Ecuador

The loss of forests is a problem that has seriously affected Ecuador for almost three decades, the most common cause being the expansion of the agricultural frontier [40]. In the country, since 2017, the Organic Code of the Environment has been in force to regulate environmental legislation that includes forest management. However, Sarabia [41] points out that this code has not been put into practice, thus ensuring that the problem is not necessary the lack of policy, which is what happens in other countries, but the lack of implementation of that policy. The importance of generating spaces for debate for the implementation of public policies is imperative for the sustainable management of forest ecosystems in Ecuador.

Table 4. Deforestation indicators in Ecuador in the period 2000-2016. Adapted from [39]

Period	Annual gross deforestation (ha /year)	Annual gross deforestation rate (%)	Annual net deforestation (ha /year)	Annual net deforestation rate (%)
2000 - 2008	108,666	-0.82	77,748	-0.58
2008 - 2014	97,918	-0.77	47,497	-0.37
2014 - 2016	94,353	-0.74	61,112	-0.48

Table 4 shows indicators of deforestation rates in Ecuador in the period 2000-2016. According to Sierra [42] the drop in the net deforestation rate in 2010 is mainly due to four structural factors that are key to understanding this shift in land use patterns: i) the intensification of rural production systems, ii) improvements in accessibility in almost all rural sectors of the country, iii) the drop in the growth rate of the population in general, and of the birth rate in particular, iv) the closure of a large part of the colonization borders due to the consolidation of property rights of the most important remaining forest areas.

Guachizaca [43], points out that deforestation in the country is commonly caused by the expansion of the agricultural frontier and the population that lives in the forests or near them, since they have been forced to convert certain forest areas into agricultural systems, even making use of forest resources to meet their most basic needs. Extreme poverty in the populations surrounding the forests has fueled phenomena not only related to the illegal expansion of the agricultural frontier, but also illegal logging and land invasion [44]. We believe that the relationship between poverty and forests moves to a new setup, where the aggravated interaction between the two is worsened by a new global scenario of political, economic and sociocultural dimensions, among others. This requires the intervention of various public, private and community actors in order to generate sustainable actions to improve the current conditions of deforestation.

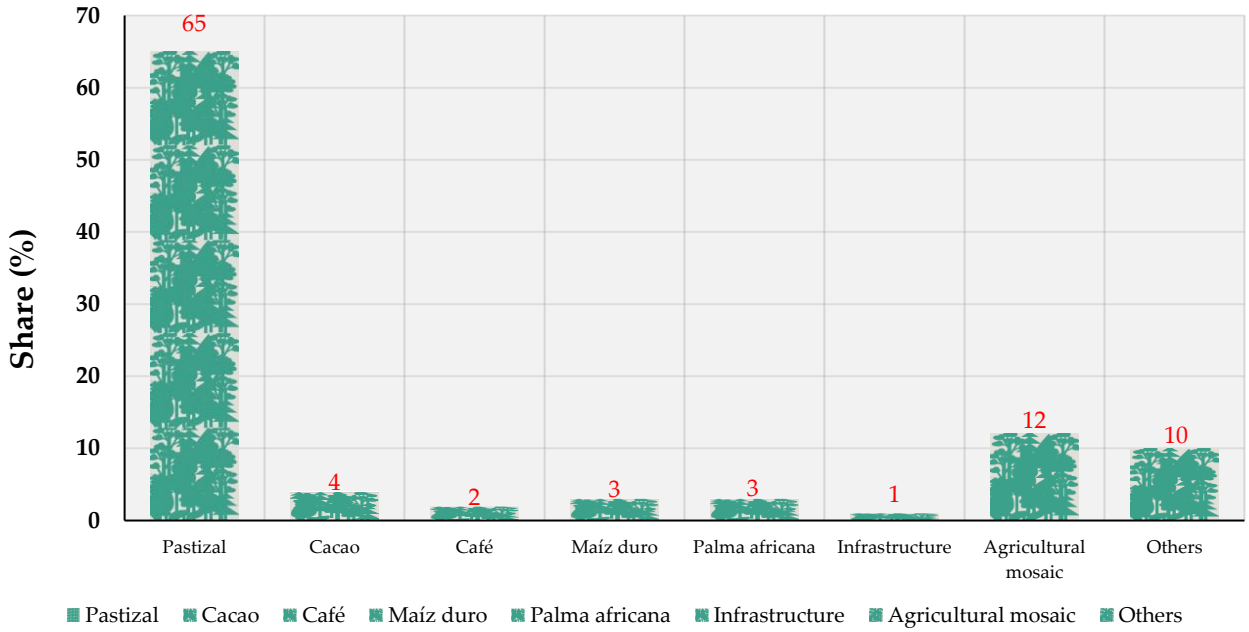

Figure 3. Transition from forest to non-forest areas in Ecuador. Adapted from [45]

In this context, **Figure 3** shows the transition from forest to non-forest areas during the 2016-2018 period, according to REDD Ecuador [45]. 65% of the forest in Ecuador became pasture, 12% to agricultural mosaics, 4% cocoa plantations, 3% hard corn plantations, 3% African palm plantations, 2% coffee plantations, more than 10% were changed in others types of coverage and, finally, 1% of the deforested area went to infrastructure and human settlements. We believe that the proper management of forests carries high costs, therefore, compensation to both the private sector, local governments and the locals, in general, for the conservation of forests, should be adequate through the generation of public policies, especially in terms of incentives.

3.2. Macroeconomic Analysis of the Forestry in Ecuador

3.2.1. National Wood Market

Globalization in the markets has had important impacts on the Ecuadorian economy and on different productive sectors, including forestry. To understand the current situation of the sector, we consider it necessary to characterize its commercial behavior abroad, as well as the level of production and consumption of timber at the national level.

The national wood market represents the commercialization of forest products at the country level [46]. In Ecuador, 750 forest species are exploited annually, 48% to obtain non-timber forest products (NTFP), 45% for timber forest products (PFM) and 7% for firewood [47]. The native species most used to obtain industrial roundwood are: Balsa (*Ochroma pyramidalis*), Sande (*Brosimum utile*), Laurel (*Cordia alliodora*), Guayacán (*Guaiacum officinale*), Podocarpus (*Podocarpus*) and Cedar (*Odorata*); among the introduced species are the Pine (*Pino radiata*) and the Eucalyptus (*Eucalyptus globules*) [11, 48]. However, low per capita income, high prices and lack of culture in the use of this resource are main factors that affect the appropriate consumption of forest resources [49].

Figures 4 and **5** show the local sales of forestry and wood extraction in Ecuador, in the period from 2006 to 2019. According to the SAIKU system of the Internal Revenue Service of Ecuador (SRI) [50], local sales of logging were USD 9.2 million in 2019 (17% less than 2018), which represented 20% of the total local sales of forestry and logging, in general, and which had an average year-by-year variation rate of -2% between 2006 and 2019.

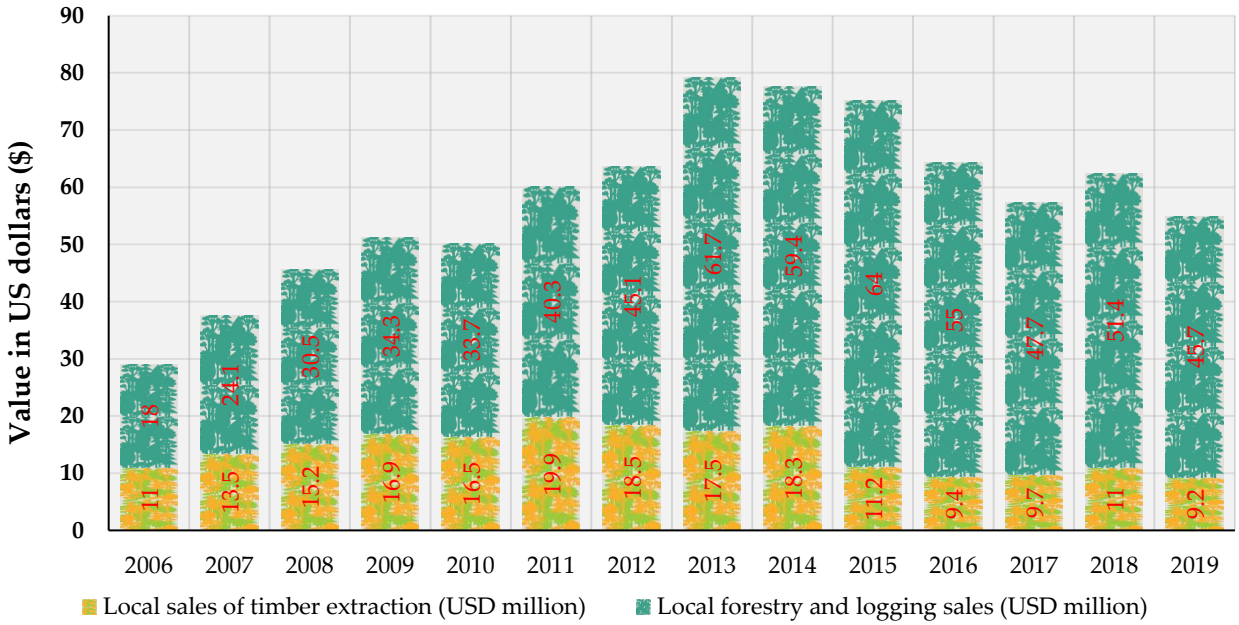

Figure 4. Local sales in Ecuador of forestry and wood extraction in the period 2006-2019. Adapted from [48]

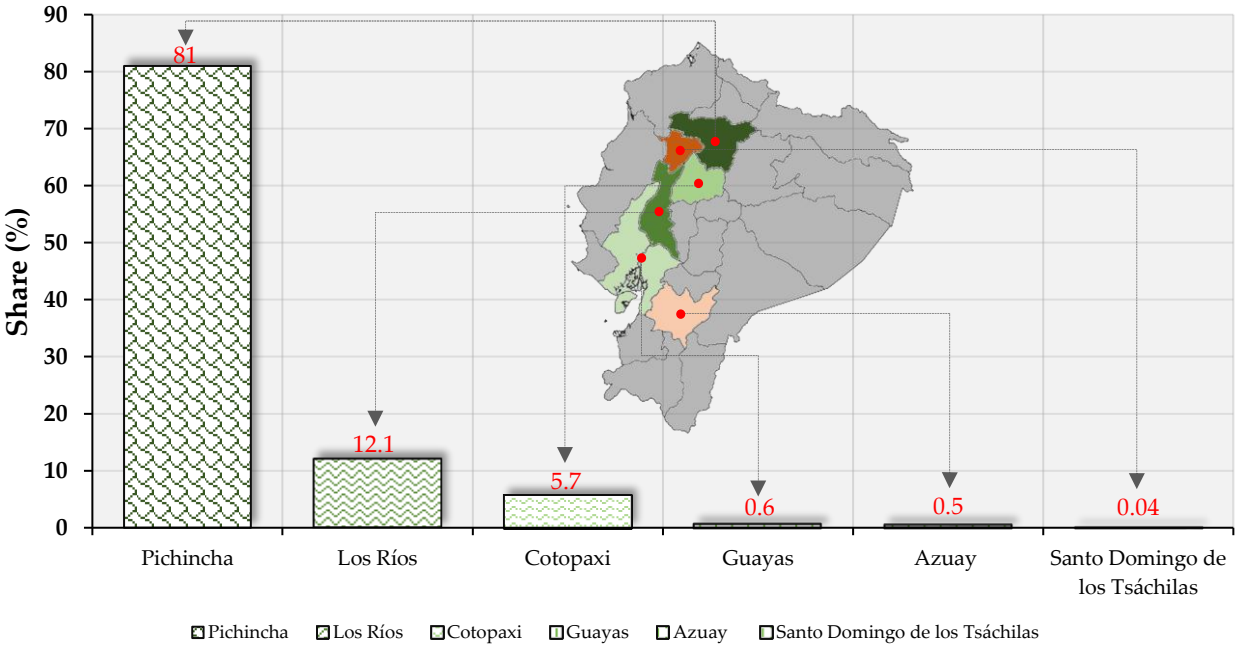

Figure 5. Participation by province in local sales of wood extraction in Ecuador 2019. Adapted from [50]

It is important to note that 98.9% of local sales in 2019 were covered by the provinces of Pichincha, Los Ríos and Cotopaxi (**Figure 5**). Based on the above, it would seem that the national

wood market in Ecuador is relatively small in relation to world consumption in economic terms. It is important to point out that there is a very important share of the extraction of wood that is not included in the statistics due to its illegal transfer [51]. This situation shows that the forest contributes less to the economy, when in reality there are many actors in the informal wood market with which higher economic values would be obtained within the national forest market.

A study by Barrantes et al. [52] has indicated the volume of waste produced in the process of industrial transformation of wood which was incorporated into the economic calculation; using the final price of the product, Ecuador loses USD 338.03 million, assuming a potential of 100% in the utilization rate. We consider that these demonstrate the importance of expanding and improving the control in the exploitation and mobilization of wood through adequate methods supported by statistical data.

3.2.2. International Wood Market

The external wood market represents the exit of timber products or raw materials from a country to different countries of the world in a legal way through a sale [53]. Ramage et al. [54], points out that the external wood market is influenced by the construction industry, by the incorporation of wood and derived materials in its construction, by its use in the construction process with steel and reinforced concrete, and also by the demand for furniture and accessories that the construction drags.

The hegemony and importance of the countries in the international wood market are related to the supply capacity, since it is a merchandise of medium to low economic density, so transport is an important factor in profitability and location plays a significant role [55]. In this context, **Table 5** shows the exports in the period 2016-2020 according to the Superintendence of Companies of Ecuador [56]. During this period, the sector's exports reflected a decreasing trend, however, as of 2019 this scenario changed. In this year the highest Free on Board value of the analyzed period was reported with 441.33 million of USD, which is 149% higher than in 2018. As of August 2020, exports reached 33% of the total reported in 2020.

Throughout the period of analysis, the exports of the sector were directed mainly to China and India according to the superintendence of companies of Ecuador in 2020 (**Table 6**). Additionally, the Ecuadorian Federation of Exporters (FEDEXPOR) [57], mentions that 19 varieties of wood were exported in 2020; raft and teak (*Tectona grandis*) were the most in demand abroad and the main destinations were China, India and United States. Currently, the national reference price for rafts ranges approximately between USD 80 and USD 100 per cubic meter of standing wood [58]. Regarding the export reference price, it is located at $3,582 per ton of sawn and cut balsa wood [11].

Regarding world exports, Ecuador has been, for 50 years, the first exporter of balsa in the world, both raw and industrialized [59]. On the other hand, teak wood is sold as a raw material and very little with added value, mostly only in blocks, to make boards for which a process with more technology and adequate equipment is required [60]. The country makes small exports to Vietnam and China; there are some secondary shipments to countries in Europe that require the wood to be legal, requesting that the wood be certified by international entities such as the Forest Stewardship Council (FSC), whose application is complex in several requested criteria. However, the country

manages national certifications that are also functional when exporting [61]. Based on the data reported, we believe that the country has a high potential for exporting products based on various woods, especially balsa and teak, acknowledging the existence of a significant international demand.

Table 5. Free on Board exports of the forestry sector in Ecuador. Adapted from [56]

Year	weight (ton)	Free On Board (USD)	Cost Average ton (USD)
2016	403.50	157,715.44	390.87
2017	391.52	144,857.86	369.99
2018	409.45	126,083.13	307.93
2019	431.33	179,646.48	416.50
Jan-Aug. 2020	141.02	267,704.54	1898.41

Table 6. Free On Board export destinations in thousands of dollars. Adapted from [57]

No	Destination	2016	2017	2018	2019	Jan-Aug. 2020
1	China	41.73	38.84	45.78	91.01	220,575
2	India	41.26	45.95	35.11	43.07	9,138
3	United States	27.92	26.36	14.11	11.58	9,056
4	Poland	2.27	1.87	5.15	4.90	6,070
6	Lithuania	4.86	4.73	4.59	4.19	4,947
7	Denmark	11.56	9.48	5.58	8.34	4,462
8	Rest of the world	28.12	17.63	15.76	16.57	13,457
	Total	**157.72**	**144.86**	**126.08**	**179.65**	**267,705**

Table 7. Main exporting companies in Ecuador and their exports in USD millions. Adapted from [62]

No	Exporter	Million - Free On Board
1	Novopan Ecuador S.A.	75,92
2	Plantaciones de balsa Plantabal S.A.	43,73
3	Delegación Ecuatoriana de Balsaflex España, DEL.E.B.ES, Cia. Ltda.	29,63
4	Aglomerados Cotopaxi S.A.	15,67
5	Enchapes decorativos S.A. Endesa	14,22
6	Bosques Tropicales S.A Botrosa	13,21
7	Diab Ecuador. S.A. Divinycell	10,91
8	Expoforestal Industrial S.A	7,36
9	International Forest Products del Ecuador S.A.	7,21
10	S.N.B. Export S.A	5,63
	Total	**223,49**
	Share of the top 10	93,14
	Industry Total	**230,08**

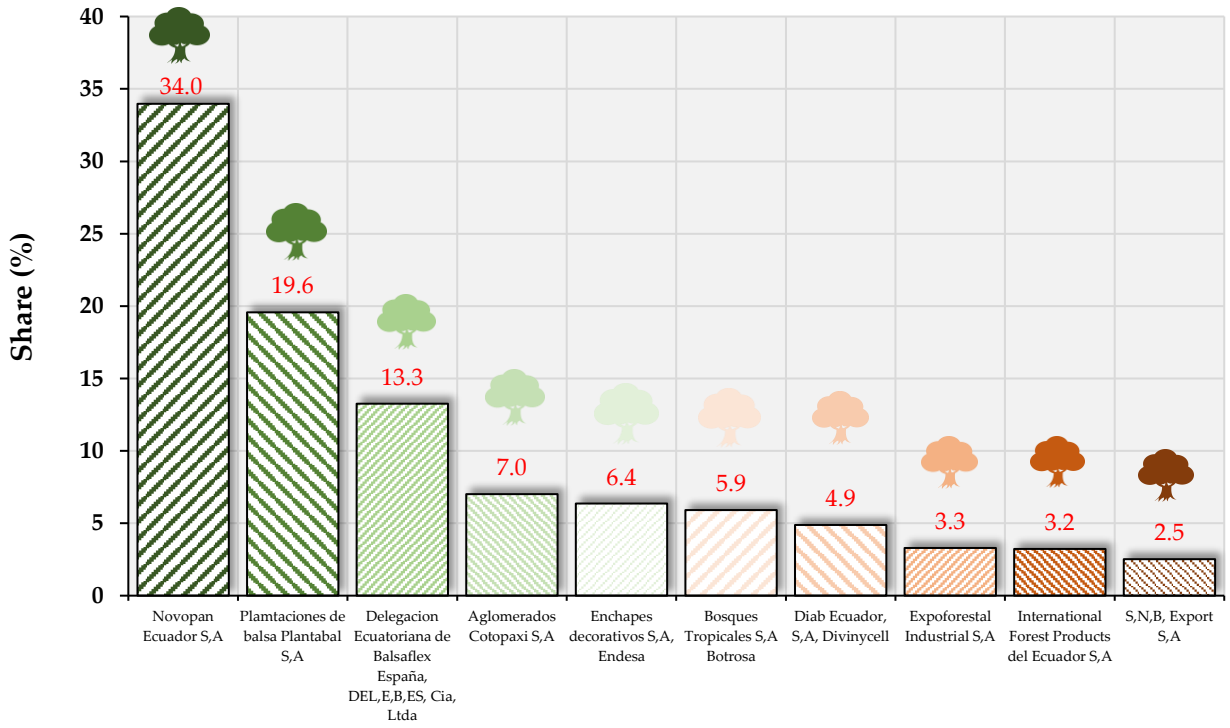

Figure 6. Main exporting companies in Ecuador and their exports expressed in millions. Adapted from [62]

Finally, **Table 7** shows the main forest export companies in Ecuador in 2019. Novopan is the first wood exporting company with a total of USD 75.92 million FOB, followed by Plantaciones de Balsa Plantabal with USD 43.73 million, respectively. 66.8% of the total exported by this sector contribute the top 3 companies in the country reported in **Figure 6**. We consider that the timber companies in the country have had a boom in recent years in terms of exports, however, the challenge is great, especially to meet the demanding world demand.

3.2.3. The forestry sector and its role in the macroeconomy

3.2.3.1. Gross domestic product (GDP)

Worldwide, countries hold natural resources that allow them to grow their economy [63]. Forestry, wood extraction and related activities, is an industry that has been developed in Ecuador in recent years, which has brought considerable economic returns to the country's economy [64]. In this context, **Table 7** shows a retrospective analysis of GDP in recent years in Ecuador. This sector added around 745.8 million of dollar in 2019, equivalent to a share of GDP of 1.04%, which was 6.8% lower compared to the figure of 2018. In 2019, 67% of GDP of this industry was generated by the provinces of Esmeraldas, Los Ríos, Cotopaxi, Pichincha and Chimborazo, as shown in **Figure 7**.

Table 8. Retrospective analysis of GDP in Ecuador 2016-2020. Adapted from [56]

Year	Forestry, wood extraction and related activities (USD)	Total GDP (USD)	Participation in the national GDP
2016	741	69,314	1.07%
2017	761	70,956	1.07%
2018	766	71,871	1.07%
2019	745	71,814	1.04%

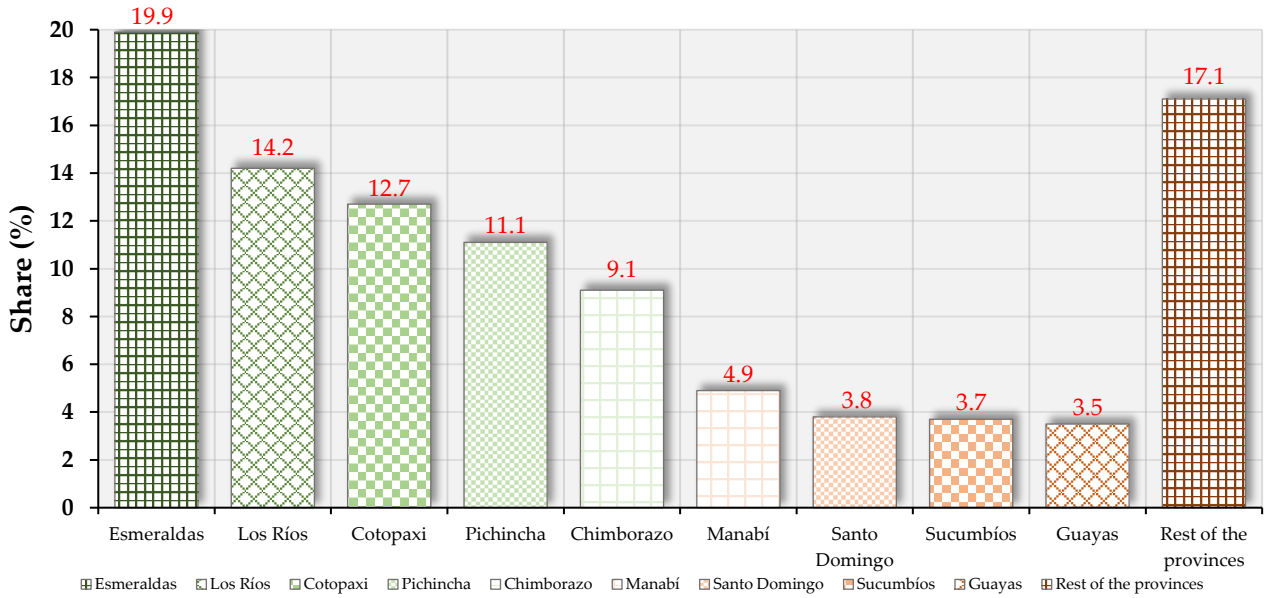

Figure 7. Participation by province of Ecuador in forestry GDP, wood extraction and related activities. Adapted from [31]

The lower contribution of the forestry sector to the total economy, in relative terms, is also reflected in the structure of exports, with forestry exports reaching only 1.04% of GDP with respect to total exports in 2019. This indicator combines the four forestry subsectors: forestry and logging, sawmilling, plywood and panel, and pulp and paper [65]. We believe that the suspension of productive activities in the country due to the Covid-19 pandemic negatively affected the Ecuadorian economy and the forestry sector has not been the exception. However, in certain sectors, it has given ways to a reengineering of processes with a view not only to their reactivation but rather to generate innovation mechanisms. Despite its little formal contribution to the national economy, the forestry industry in Ecuador plays an important role in generating income and employment.

3.2.3.2. Employment generation

Good-quality jobs provide people with the means to lift themselves out of poverty, which in turn helps countries to achieve greater economic and social stability [66]. The International Tropical Timber Organization (ITTO) [67] points out that the generation of employment is transcendental for the development of a region, which still has to face the social challenge of reducing income

inequalities, expanding social protection and reducing the weight of the informal sector in the region's economy. In this context, **Table 9** is presented, which shows the size and number of companies that existed in Ecuador for the year 2020.

Table 9. Size of companies and number of companies in the forestry sector in Ecuador. Adapted from [68]

No	Forestry and logging	No. Companies	Share (%)
1	Big	14	**6.9**
2	Median	24	**11.8**
3	Small	34	**16.7**
4	Micro Enterprise	132	**64.7**
5	**Total**	**204**	**100**

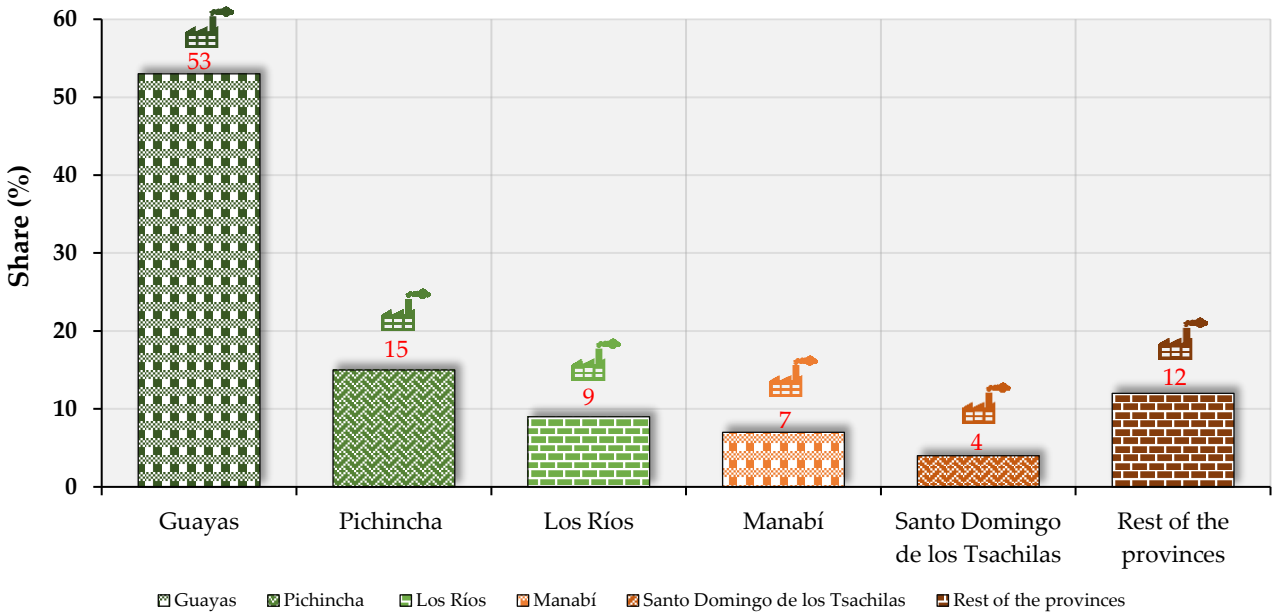

Figure 8. Participation (%) of the number of companies by province. Adapted from [68]

There are currently 204 companies dedicated to forestry and wood extraction in Ecuador [68]. **Figure 8** shows the participation of the number of companies by province dedicated to the extraction of wood. Ecuadorian forestry companies are located mainly in the province of Guayas (53%), followed by Pichincha (15%). According to the ITTO [67], the forestry sector generates around 235,000 direct jobs and thousands of additional indirect jobs. The importance of this sector lies in the fact that a large part of this employment is generated at the rural level and in small cities where a lot of craft activity is concentrated [69]. Additionally, illegal logging activity, which occurs in the country, should be considered. Probably this activity generates certain items that contribute to the reduction of poverty in the region, however, the jobs generated from an illegal activity do not meet the criteria required by law, such as social security, fair salary, compensation for accidents, legal benefits, among others [70]. For that we consider that the forestry activity in Ecuador still has a great challenge to fulfill in this fact.

4. CONCLUSIONS

The results of this study were based on a descriptive analysis, where most of the data included statistics that were calculated from the existing bibliographic data. This study provides a general description of the state-of-art forest land use in Ecuador and of the contribution of forestry to the country's economy is in terms of employment generation and GDP. In this regard, it is likely that if the current use of natural forests continues to increase in terms of deforestation, conditions will quickly become critical for the timber industry, so prompt action should be taken. On the other hand, we believe that in recent years Ecuador has experienced a great evolution in logging, which offers an excellent perspective as a source of income for the nation. However, it can only continue if organized production programs are implemented to enable the sustainability of the products. We believe that the trade in wood products in the country presents great challenges in terms of the systems used to report and verify statistical information. Finally, we believe that in order to better understand the role played by the forestry sector in the economy of Ecuador, studies should be carried out at the regional, provincial, cantonal and parish levels that address local particularities in order to have a more comprehensive analysis.

SUPPLEMENTARY MATERIALS

Not the case.

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CONFLICT OF INTEREST

The author does not declare any conflict of interest.

APPENDIX

Not the case.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu: *Starea pădurilor din Ecuador şi contribuția acestora la Produsul Intern Brut*

Introducere: *Ecuador este una dintre cele 12 ţări ale Americii de Sud, fiind una dintre ţările megadiverse şi având o suprafaţă de 256,370 km². Se estimează că, în Ecuador, există mai mult de 1250 de specii de plante pe km², care aparţin unui număr de 136 de familii, multe dintre ele fiind endemice. 40% din teritoriul ţării este acoperit de păduri naturale (în majoritate localizate în bazinul Amazonului) şi 1% cu plantaţii forestiere; 45% din suprafaţa ţării este pretabilă pădurilor. Un număr de 750 de specii forestiere sunt încadrate în grupa celor utilizabile, dintre care 48% pentru produse accesorii, 45% pentru produse lemnoase şi 7% pentru foc. În ultimii ani, produsele forestiere lemnoase din Ecuador au fost caracterizate de o performanţă economică mai ridicată datorită exporturilor, înregistrându-se o creştere graduală în acest sector. Între 2009 şi 2018, sectorul forestier a contribuit, în medie, cu 1,3% la PIB, generând un număr de 324,000 locuri de muncă şi demonstrând că sectorul are un potenţial economic ridicat pentru ţară, motiv pentru care devine importantă evaluarea continuă a datelor macroeconomice pentru a le utiliza în scopul planificării pentru a întruni condiţiile pieţei şi a asista luarea deciziei în domeniile public şi privat. Obiectivele acestui studiu au fost următoarele: i) de a identifica şi caracteriza pădurile la nivel naţional şi ii) de a analiza contribuţia lor în economia Ecuadorului sub raportul generării de locuri de muncă şi a participării la PIB-ul ţării.*

Materiale şi metode: *Studiul s-a implementat prin consultarea sistematică a literaturii cu privire la perspectivele macroeconomice relaţionate cu producţia forestieră din Ecuador. S-a realizat o sinteză cu privire la distribuţia pădurilor şi o analiză a participării sectorului la PIB-ului ţării, având la bază studii şi documente guvernamentale oficiale. În plus, s-au consultat articole ştiinţifice recente din bazele de date naţionale şi internaţionale cu scopul de a extinde analiza. Pentru accesarea surselor de date s-au folosit cuvinte cheie definite în raport cu scopul şi obiectivele studiului. Raportat la distribuţia pădurilor în Ecuador, studiul a abordat trei tematici: distribuţia pe categorii, stratificarea în raport cu suprafaţa ocupată şi funcţiile pădurilor şi, respectiv, analiza retrospectivă a suprafeţelor ocupate de păduri. Analiza aspectelor macroeconomice a luat în considerare piaţa internă a lemnului în perioada 2016-2019, piaţa externă a lemnului şi exporturile în perioada 2006-2019, precum şi rolul sectorului forestier în macroeconomie prin analiza retrospectivă a contribuţiei acestuia la PIB-ul ţării şi la generarea de locuri de muncă în perioada 2016-2020. Informaţia colectată din diverse baze de date a permis realizarea unor interpretări pe baza unui număr relativ mare de variabile.*

Rezultate şi discuţii: *Suprafaţa totală a pădurilor din Ecuador este de 12,385,973 hectare, reprezentând 38.8% în regiunea de coastă/litoral, 30.4% în regiunea Anzilor, 30.1% în regiunea Amazonului şi 0.8% în suprafeţe din alte categorii. În regiunea de coastă, terenurile sunt destinate, în principal, culturilor permanente, urmate de culturi pasagere, terenuri necultivate, pășuni şi alte utilizări. În regiunea Anzilor, predomină pădurile şi terenurile forestiere. În regiunea Amazonului, predomină pădurile naturale de altitudine joasă, pădurile montante şi piemontane. Ca rezultat la schimbării folosinţei terenurilor, o parte din pădurile Ecuadorului au devenit pășuni, terenuri agricole, plantaţii de cacao, porumb, palmier, cafea şi, respectiv, terenuri destinate infrastructurii. În 2019, piaţa naţională lemnului a fost caracterizată de o valoare de 9.2 milioane de dolari in 2019 (17% mai puţin faţă de 2018). 98.9% din această sumă a fost generată de provinciile Pichincha, Los Ríos şi Cotopaxi. Novopan este cea mai mare companie exportatoare (75.92 milioane dolari), urmată de Plantaciones de Balsa Plantabal cu 43.73 milioane de dolari. În 2019, sectorul forestier a contribuit la PIB cu 1.04%.*

Concluzii: *Acest studiu furnizează o descriere generală cu privire la pădurile şi sectorul forestier din Ecuador precum şi cu privire la contribuţia acestuia la economia ţării. Utilizarea curentă intensivă a pădurilor poate să conducă la probleme pentru sector, motiv pentru care trebuie luate măsuri prompte. În ultimii ani s-a înregistrat o creştere a sectorului de exploatare a lemnului care a şi provocat provocări însemnate legate de îmbunătăţirea activităţii.*

Cuvinte cheie: *Produs Intern Brut, economie forestieră, Ecuador, statistici, sectorul forestier din Ecuador.*

REFERENCES

1. Nawaz A., Farooq M., 2021: Agricultural Practices and Sustainable Management in South Asia. Life on Land, 36-48.

2. Lefeuvre N, Keller N., Plagnat-Cantoreggi P., Godoong E., Dray A., & Philipson C. D., 2022: The value of logged tropical forests: A study of ecosystem services in Sabah, Borneo. Environmental Science & Policy, 128, 56-67.
3. Union of Forest Research Organizations IUFRO, 2020: Interconnecting forests, science and people. Available online at: https://www.iufro.org/ (accessed on 26/01/2022).
4. Maroyi A., 2022: Traditional uses of wild and tended plants in maintaining ecosystem services in agricultural landscapes of the Eastern Cape Province in South Africa. Journal of Ethnobiology and Ethnomedicine, 18(1), 1-20.
5. Food and Agriculture Organization of the United Nations FAO, 2015: The contribution of the forestry sector to national economies, 1990-2011. Available online at: https://www.fao.org/3/i4248s/I4248S.pdf (accessed on 26/01/2022).
6. Nilsson S., Bull G., 2005: Global wood supply analysis. 46th Session of the FAO Advisory Committee, Vancouver Canada, 31st May. Available online at: https://www.researchgate.net/profile/Gary-Bull/publication/267778655_Global_Wood_Supply_Analysis/links/54b84d6c0cf269d8cbf6cb02/Global-Wood-Supply-Analysis.pdf (accessed on 28/01/2022).
7. de Wit M., Junginger M., & Faaij A., 2013: Learning in dedicated wood production systems: past trends, future outlook and implications for bioenergy. Renewable and Sustainable Energy Reviews. 19, 417-432.
8. Food and Agriculture Organization Corporate Statistical Database FAOSTAT, 2021: World Food and Agriculture. Statistical. Available online at: https://www.fao.org/faostat/en/#home (accessed on 26/01/2022).
9. Li Y., Mei B., & Linhares T., 2019: The economic contribution of the world's forest sector. Forest Policy and Economics, 100, 236-253.
10. Blackman A., Epanchin R., Siikamaki J., & Velez D., 2014: Biodiversity Conservation in Latin America and the Caribbean. Routledge, New York, NY, US. Available online at: https://www.taylorfrancis.com/books/mono/10.4324/9781315848433/biodiversity-conservation-latin-america-caribbean-allen-blackman-rebecca-epanchin-niell-juha-siikam%C3%A4ki-daniel-velez-lopez (accessed on 28/01/2022).
11. Redín M., 2016: Financial evaluation and risk analysis of a forestry investment project developed in Ecuador. Quito: Universidad Andina Simón Bolívar, Master's Program in Finance and Risk Management.
12. Paligorov I., Ivanov I., Kovacheva S., & Dragozova E., 2014: Ecosystem of the Forest Landscape and Conflict of Interests of Stakeholders. Economics and Business. 25, 61-67.
13. Mejia E., Pacheco P., 2013: Forest harvesting and timber markets in the Ecuadorian Amazon (Vol. 97). CIFOR. Available online at: https://books.google.ro/books?hl=ro&lr=&id=fjvWBQAAQBAJ&oi=fnd&pg=PP1&dq=Mejia+E.,+Pacheco+P.,+2013:+Aprovechamiento+forestal+y+mercados+de+madera+en+la+Amazon%C3%ADa+ecuatoriana+(Vol.+97).+CIFOR.&ots=WZ37PVzX3R&sig=vajYtmp5lpw1GRnyx79NXB90-Lo&redir_esc=y#v=onepage&q=Mejia%20E.%2C%20Pacheco%20P.%2C%202013%3A%20Aprovechamiento%20forestal%20y%20mercados%20de%20madera%20en%20la%20Amazon%C3%ADa%20ecuatoriana%20(Vol.%2097).%20CIFOR.&f=false (accessed on 15/02/2022).
14. Zambrano C., León L. R., 2016: A look. Republic of Ecuador. Dominio de las Ciencias, 2(3), 55-66.
15. Roy B., Zorrilla M., Endara L., Thomas D. C., Vandegrift R., Rubenstein J. M., Policha T., Rios B.T., & Read, M., 2018: New mining concessions could severely decrease biodiversity and ecosystem services in Ecuador. Tropical Conservation Science, 11, 1940082918780427.
16. Ortega H., Rodes M., Cisneros D. F., Guerra N., de Vargas-Machuca K. G., Sánchez J. C., Armijos O., Caceres A., Reyes P., Quezada A.B., Szekely P., Rojas O.R., Szekely D., & Yánez M. H., 2021: Red

List assessment of amphibian species of Ecuador: A multidimensional approach for their conservation. PloS one, 16(5), e0251027.
17. Valencia R., Balslev H., Paz Y., & Miño C., 1994: High tree alpha-diversity in Amazonian Ecuador. Biodiversity and Conservation, 3, 21–28
18. Olson D., Dinerstein E., 2002: The Global 200: Priority Ecoregions for Global Conservation. Annals of the Missouri Botanical Garden, 89, 199–224.
19. León S., Valencia R., Pitman N., Endara L., Ulloa C. U., & Navarrete H., 2019: Red book of the endemic plants of Ecuador.
20. Food and Agriculture Organization of the United Nations FAO, 2020: Global forest resources assessment 2020: main report. Rome. Available online at: https://doi.org/10.4060/ca9825en (accessed on 26/01/2022).
21. López N., Muñoz J., 2017: Forestry production, an activity with high potential in Ecuador, requires a change of vision. Zero Latitude Forests, 7(1).
22. Social, Environmental and Climate Assessment Procedures SECAP, 2014: Managing risks to create opportunities. Available online at: https://www.ifad.org/en/secap (accessed on 26/01/2022).
23. Acosta A., 2011: Extractivism and neo-extractivism: two sides of the same curse. Beyond Development. 1, 83-118.
24. Armas M., Paredes L. U., 2019: Use of forest plantations in Imbabura, Ecuador. Amazon Magazine Science and Technology, 8(2), 98-106.
25. González V., Fries A., Zeilinger J., Homeier J., Paladines J., & Bendix J., 2018: Estimation of above ground biomass in a tropical mountain forest in southern Ecuador using airborne LiDAR data. remote sensing, 10(5), 660.
26. Morland C., Schier F., Janzen N., & Weimar H., 2018: Supply and demand functions for global wood markets: specification and plausibility testing of econometric models within the global forest sector. Forest Policy and Economics, 92, 92-105.
27. The World Bank, 2016: Forests Generate Jobs and Incomes. Available online at: https://www.worldbank.org/en/topic/forests/brief/forests-generate-jobs-and-incomes#:~:text=Forests%20generate%20wealth%20and%20millions,over%20%24600%20billion%20each%20year (accessed on 26/01/2022).
28. Angelsen A., Larsen H., & Olsen C., 2012: Measuring livelihoods and environmental dependence: Methods for research and fieldwork. Routledge. Available online at: https://www.taylorfrancis.com/books/mono/10.4324/9781849775694/measuring-livelihoods-environmental-dependence-arild-angelsen-helle-overgaard-larsen-carsten-smith-olsen (accessed on 16/03/2022).
29. Powers W., 2012: The Value of Value Added-Measuring global engagement with gross and value-added trade. World Economics-Abingdon, 13(4), 19.
30. The World Bank, 2020: Agriculture, forestry, and fishing, value added (% of GDP). Available online at: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS (accessed on 26/01/2022).
31. Sanchez M., Vayas T., Mayorga F., & Freire C., 2020: Ecuador timber sector, overview. Obtenido de Universidad Técnica de Ambato: Available online at: https://blogs.cedia.org.ec/obest/wp-content/uploads/sites/7/2020/06/Sector-maderero-Ecuador-aprobado.pdf (accessed on 26/01/2022).
32. Food and Agriculture Organization of the United Nations FAO, 2019: Current situation of the forestry sector in Ecuador. Available online at: https://www.fao.org/3/j4524s/j4524s05.htm#TopOfPage (accessed on 26/01/2022).
33. Zhao P., Wan J., 2021: Land use and travel burden of residents in urban fringe and rural areas: An evaluation of urban-rural integration initiatives in Beijing. Land Use Policy, 103, 105309.
34. National Institute of Statistics and Censuses Ecuador INEC, 2016: Surface Survey and Continuous Agricultural Production ESPAC. Available online at: https://docplayer.es/52999013-Encuesta-de-superficie-y-produccion-agropecuaria-continua-espac-2016.html (accessed on 26/01/2022).

35. Surface Survey and Continuous Agricultural Production Ecuador ESPAC, 2019: Available online at: https://www.ecuadorencifras.gob.ec/documentos/web-inec/Estadisticas_agropecuarias/espac/espac-2019/Presentacion%20de%20los%20principales%20resultados%20ESPAC%202019.pdf (accessed on 26/01/2022).
36. Instituto Geográfico Militar IGM, 2017: Atlas rural del ecuador primera edición año 2017, por Instituto Geográfico Militar. Primera. Quito: Journal of Chemical Information y Modeling
37. Otavo S., Echeverría C., 2017: Fragmentación progresiva y pérdida de hábitat de bosques naturales en uno de los hotspot mundiales de biodiversidad. Revista mexicana de biodiversidad, 88(4), 924-935.
38. Jadán O., Torres B., Selesi D., Peña D., Rosales C., & Günter S., 2016: Floristic diversity and structure in traditional cacao plantations and natural forest (Sumaco, Ecuador). Colombia Forestal, 19(2), 129-142.
39. Ministry of the Environment of Ecuador MAE, 2015: Natural Heritage Statistics. Data on forests, ecosystems, species, carbon and deforestation of continental Ecuador. Available online at: http://suiadoc.ambiente.gob.ec/documents/10179/346525/ESTADISTICAS+DE+PATRIMONIO+FINAL.pdf/b36fa0a7-0a63-4484-ab3e-e5c3732c284b;jsessionid=CWcoTreH0UQH1FdyUU-WM8pg?version=1.1 (accessed on 26/01/2022).
40. Wunder S., Albán M., 2008: Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador. Ecological Economics. 65(4), 685-698.
41. Sarabia R., 2021: Protection of forest ecosystem services. position of environmental criminal law. Agroecosystems Scientific Journal, 9(1), 121-128.
42. Sierra R., 2010: Historical and geographical patterns and determinants of deforestation in Ecuador, 1950-2010 and future trends. First national meeting on forests, forest genetic resources and agroforestry. 35.
43. Guachizaca I., 2018: Strengthening of local sustainable ways of life of the communities settled in the buffer zone of the Podocarpus National Park and conservation of the spectacled bear in the canton of Palanda, province of Zamora Chinchipe. Master's thesis, PUCE.
44. Altamirano M., Mercedes I., 2010: Civil society and socio-environmental conflicts due to illegal logging in the Yasuní National Park: (The Redwoods National Park a model to follow). Master's thesis, Quito: FLACSO Sede Ecuador.
45. REDD Ecuador, 2018: Deforestation and forest degradation. Available online at: https://www.proamazonia.org/wp-content/uploads/2022/02/3-Deforestacion.pdf (accessed on 26/01/2022).
46. Pérez M., Ndoye O., Eyebe A., & Puntodewo A., 2000: Spatial characterisation of non-timber forest products markets in the humid forest zone of Cameroon. The International Forestry Review, 71-83.
47. Garcia O., 2019: Historical behavior of forest use in the province of Manabí in the period 2014-2018 (Bachelor's thesis, Jipijapa-UNESUM).
48. Ministry of the Environment of Ecuador MAE, 2013: National Forest Control System. Available online at: https://www.ambiente.gob.ec/wp-content/uploads/downloads/2015/07/CONTROL-FORESTAL.pdf (accessed on 26/01/2022).
49. Palacios W., 2004: Forest species communities in tropical rain forests of Ecuador. Lyonia, 7(1), 33-40.
50. Internal Revenue Service SRI, 2022: Plataforma SAIKU. Ventas locales de extracción de madera. Available online at: https://www.gob.ec/sri (accessed on 26/01/2022).
51. De Castro F., 2015: Environmental governance in Latin America (pp. 13-38). B. Hogenboom, & M. Baud (Eds.). Buenos Aires: Clacso. Available online at: https://pure.uva.nl/ws/files/2495586/159718_472319.pdf (accessed on 10/03/2022).

52. Barrantes G., Chaves H., & Vinueza M., 2001: The Forest in Ecuador A transformed vision for development and conservation, COMAFORS. Available online at: http://comafors.org/biblioteca/publicaciones/el-bosque-en-el-ecuador-402.html (accessed on 26/01/2022).
53. Kaplinsky R., Memedovic O., Morris M., & Readman J., 2003: The global wood furniture value chain: What prospects for upgrading by developing countries. UNIDO Sectoral Studies Series Working Paper.
54. Ramage M., Burridge H., Busse M., Fereday G., Reynoldsa T., Shah D., Wu G., Yu L., Fleming P., Densley D., Allwood J., Dupree P., Linden P., & Schermane O., 2017: The wood from the trees: The use of timber in construction. Renewable and Sustainable Energy Reviews. 68, 333-359.
55. Murphy J., 2012: Global production networks, relational proximity, and the sociospatial dynamics of market internationalization in Bolivia's wood products sector. Annals of the Association of American Geographers, 102(1), 208-233.
56. Superintendence of Companies Ecuador, 2020: Exports nationwide. Available online at: https://www.supercias.gob.ec/portalscvs/ (accessed on 26/01/2022).
57. Ecuadorian Federation of Exporters FEDEXPOR, 2021: Exports nationwide. Available online at: https://www.fedexpor.com/ (accessed on 26/01/2022).
58. Accion Ecologica, 2020: Raft in Ecuador #6: Plantations, wild populations and new spaces occupied by the raft. Available online at: https://www.accionecologica.org/balsa-en-ecuador-6-plantaciones-poblaciones-silvestres-y-nuevos-espacios-ocupados-por-la-balsa-2/(accessed on 26/01/2022).
59. Galiano J., 2020: Financing plan for a company dedicated to the production and export of gummed raft in the province of Manabí. (Bachelor's thesis, Universidad Casa Grande. Departamento de Posgrado). Available online at: http://200.31.31.137:8080/handle/ucasagrande/2490 (accessed on 26/01/2022).
60. Vizcarra V., 2015: Export of teak wood. Economic and environmental effect in Ecuador (Master's thesis, University of Guayaquil Faculty of Economic Sciences). Available online at: http://repositorio.ug.edu.ec/handle/redug/12131 (accessed on 26/01/2022).
61. Forest Stewardship Council FSC, 2021: National Standard for Responsible Forest Management. Available online at: https://ec.fsc.org/es-ec (accessed on 26/01/2022).
62. Holguín B., Delgado D., 2019: Economic study of the behavior of wood in Ecuador in recent years. 2009-2017.
63. Rudra N., Jensen N., 2011: Globalization and the politics of natural resources. Comparative Political Studies. 44(6), 639-661.
64. Vizuete D.D., Montoya A.G., 2020: Challenges Faced by the Ecuadorian Forests and Forest Industry. Revista Pădurilor, 135(4), 001-056.
65. Olmos V., 2022: Forestry and the forest products sector: Production, income and employment, and international trade. Forest Policy and Economics, 135, 102648.
66. World Bank, 2021: Annual report 2021. Available online at: https://www.bancomundial.org/es/about/annual-report (accessed on 26/01/2022).
67. International Tropical Timber Organization ITTO, 2022: Job creation. Available online at: https://www.itto.int/about_itto/ (accessed on 26/01/2022).
68. National Finance Corporation CFN, 2020: Sector file. Forestry and logging. Submanagement of analysis of products and services. Available online at: https://www.cfn.fin.ec/wp-content/uploads/downloads/biblioteca/2021/fichas-sectoriales-3-trimestre/Ficha-Sectorial-Silvicultura-y-extraccion-de-madera.pdf (accessed on 26/01/2022).
69. Pérez E., 2004: The Latin American rural world and the new rurality. Nómadas, 180-193.
70. Fanelli J., Jiménez J., & López I., 2015: Environmental tax reform in Latin America. Available online at: https://repositorio.cepal.org/handle/11362/39782 (accessed on 26/01/2022).

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THE ROLE AND USE OF FOREST RESOURCES IN ECUADOR: A SYSTEMATIC LITERATURE REVIEW

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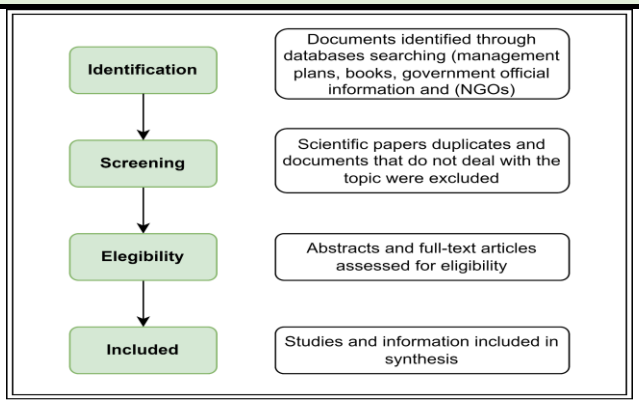
HIGHLIGHTS

- The role and use of forest resources in Ecuador are divided in exploitation and conservation.
- NTFP in Ecuador plays a key role in urban and rural areas to generate employment and income for the population.
- The production of wood and subproducts is the fifth key industry for the Ecuadorian economy.

GRAPHICAL ABSTRACT



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ABSTRACT

The principal use of the forest in Ecuador has been to extract wood to generate income. Based on a systematic literature review, this study presents a thematic overview of the legal framework, describes the uses of TFP and NTFP, and finally analyses the role of forest resources in the Ecuadorian economy. Methodologically, the information was divided in four stages: i) identification, ii) screening, iii) eligibility and iv) inclusion. The results of the research indicates that Ecuadorian policies can be emphasized to promote forest control with sustainable forest management practices including forest certifications. Consequently, the role and use of forest resources can be divided in exploitation and conservation. In addition, the economic contribution of forest resources to the national economy is the consequence of the policies applied with exploitation and conservation approaches. Finally, to increase the participation in national and international markets, the forest sector could be addressed in the potential use of non-timber forest products and not only in the use of timber forest products.

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1. INTRODUCTION

The main use of the forest has been to extract wood in order to produce goods and services, maximizing economic income [1]. In this sense, the notion of sustainable management in the forestry sector arises from the declaration of principles for the sustainable management of forests [2] and involves stages such as: i) strategic planning, ii) monitoring, iii) evaluation, iv) human and financial resources, and v) efficacy [3-7]. Additionally, forest management includes alternatives based on the capacities, objectives and limitations of the regulatory framework for forestry activity [8], but its main challenge is the use of forests with a level of intensity that allows productivity without compromising the functioning of ecosystems [9].

The identification of benefits generated by the forest includes rights, obligations, incentives and restrictions that promote better administration and management of forest lands [10]. These benefits related with the state of forest and income must be perceived with a similar level of importance by the stakeholders: community, public and private sector [11].

In the last two decades, the relationship between forest management and protection has evolved through the incorporation of established indicators to measure and track the state and biological richness of forests [12]. Considering that the greatest forest wealth is in tropical ecosystems [13], there is great potential for harvesting timber (TFP) and non-timber forest products (NTFP) [14].

TFPs are represented as fibers (timber and wood fuel) [15], while the Common International Classification of Ecosystem Services [16], describes to TFPs as materials/biomass (timber), which are supported by forest species distributed throughout the territories [17]. Complementary, NTFPs are considered as biological components resulting from forest exploitation under natural conditions [18, 19]. For instance, the main TFP produced in Ecuador are chipboard, boards, medium-density fibreboard (MDF) panels, pulp and paper and carbon storage, while the principal NTFP are linked to ecosystem services such as regulation of the hydrological cycle and habitats to maintain biodiversity [20], and categories of use such as apiarian, food, food additive, medicinal, social and toxic (contain poisonous agents for vertebrates) [21].

The Ecuadorian continental territory has an area of 24,898,396 hectares [22], and has a classification of 91 ecosystems, of which 71.43% are forests, 12.09% shrubs and 16.48% herbaceous [23]. This classification has been provided by a combination of environmental, hydric, biotic and topographic criteria according to the national environmental authority. The most representative forest cover area corresponds to the lowland evergreen forests, located mainly in the Amazonian natural region [24]. Nevertheless, many of these forests have been affected by logging due to the preference of agricultural activities [23]. One of the government mechanisms that regulates the use of forest resources is forest certification. According to [25], there are at least 10 certified forestry companies that mainly produce products such as lumber, plywood, veneers.

The restoration and sustainable use of forests is one of the sustainability objectives for Ecuador according to the 2030 national plan [26]. Additionally, other programs and actions that the

government is implementing are oriented towards the valuation of forests, management of native forests, reforestation, and development of an efficient system for the control of exploitation [27].

The knowledge of the reality about the use of forest resources is important in forest management because it allows developing a legal, productive and economic analysis towards the identification of benefits and their potential use. In this sense, this article conducts a systematic literature review of journal articles on forest management and the use of forest resources in Ecuador. The objectives of this paper were to: i) present a thematic overview of the legal framework in Ecuador, ii) describe the main uses of forest resources divided in timber and non-timber forest products and iii) analyze the role of forest resources in the Ecuadorian economy.

2. MATERIALS AND METHODS

The information related to forest management and the use of forest resources in Ecuador was collected from peer-reviewed research articles and other sources. It included sources in Spanish and English languages available in scientific databases, management plans, books, government official information and Non-Governmental Organization (NGOs). The search of information specifically mentioned "sustainable forest management", "TFP and NTFP", "forest governance" and "forest resources" from a social science approach. For a better understanding, the methodological process for the literature review has been divided and presented in a flow diagram sifting process, considering four parts: i) identification, ii) screening, iii) eligibility and iv) inclusion **Figure 1** [28].

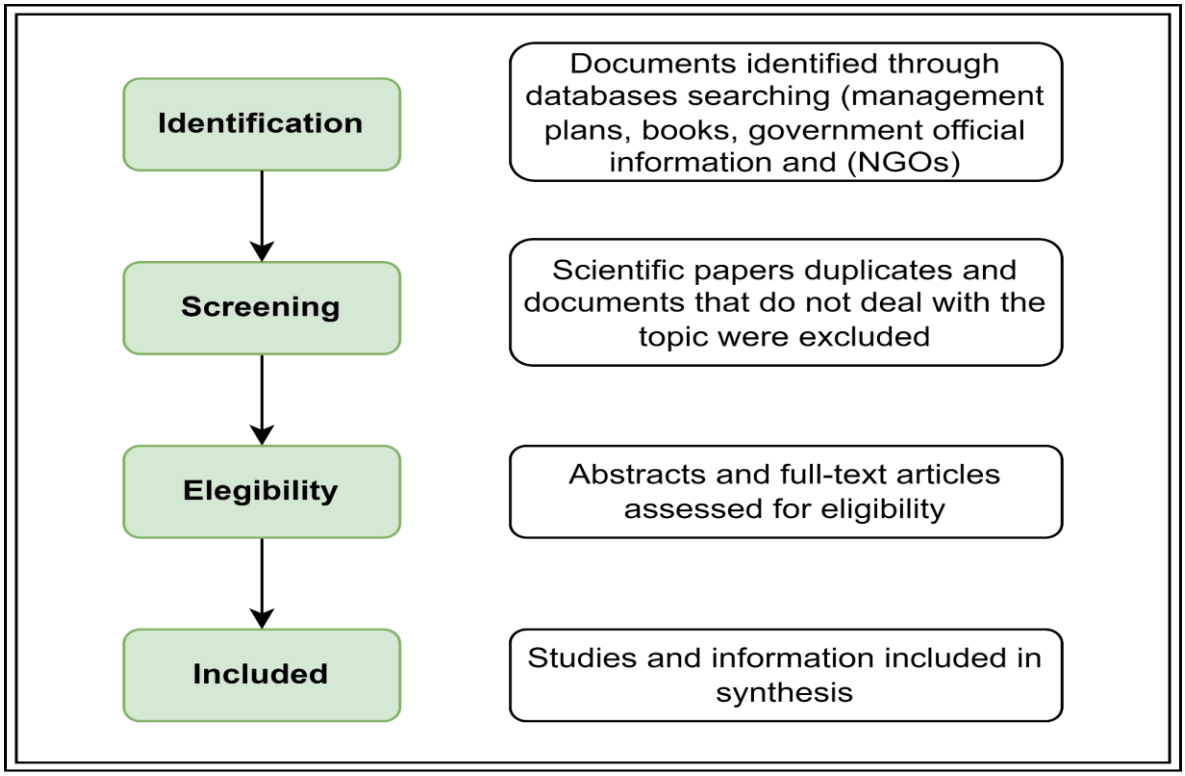

Figure 1. Methodological research process, presented according to the Prisma Diagram [28].

The review was based on a quantitative and qualitative content analysis, summarizing the main insights for the central research topics such as: i) legal framework for the management and use of natural resources, ii) use of forest resources (TFP and NTFP) and, iii) an economic perspective.

3. RESULTS

3.1. Legal Framework for the Management and Use of Forest Resources

The legal regulatory framework for the management of natural resources corresponds to the functions that each state has [29]. The approach of forest policies in Ecuador emerged from the 70s including criteria of community forestry, agroforestry and forest management. In the following decade, provision and cultural environmental services are recognized, trying to reduce the pressures on the territory of the communities. Finally, starting in the 1990s, legal instruments were developed for the management and use of natural resources, including forest resources. [10]. The Ecuadorian Forest policies are compiled according to their hierarchy in **Table 1.**

Table 1. Legal framework for the use and management of forest resources.

Type of law	Purpose of the Act	Year	Reference
Constitution of the Republic of Ecuador	It is the set of fundamental norms that protect rights and freedoms, organize the State and democratic institutions and promote economic and social development.	2008	[30]
Organic Code of the Environment	Guarantee the rights of the people to live in a healthy and ecologically balanced environment, as well as protect the rights of nature.	2017	[31]
Organic law on incentives for production and prevention of tax fraud	Provide economic incentives for afforestation and reforestation with commercial purposes	2014	[32]
Unified Text of Secondary Legislation, Environment	Establish basic environmental policies for the management of natural resources	2003	[33]
Organic Law for the reactivation of the economy strengthening of dollarization and modernization of financial management	Acquire goods related to research and technology that improve productivity	2017	[34]
Organic Law for Productive Promotion, Attraction of Investments, Employment Generation and Fiscal Stability and Balance	Regulate behaviors that are harmful to health and encourage activities for the management of natural resources	2018	[35]
Norms for Sustainable Forest Management of Humid Forests	Regulate forest management of humid forests, using the principles, criteria and indicators established to promote sustainable forest management.	2015	[36]
Procedures to Authorize the Harvesting and Cutting of Wood	It establishes the administrative procedures to authorize the sustainable use of the timber forest resources of the humid, Andean and dry natural forests; from cultivated forests: forest plantations, planted trees, trees from natural regeneration in crops; the pioneer formations; of trees in agroforestry systems; and, forest products other than wood.	2010	[37]
Norms for the Management of Andean Forests	Regulates the management of the Andean Forest, its resources and its uses.	2006	[38]

Type of law	Purpose of the Act	Year	Reference
Standards for Sustainable Forest Management of Dry Forests	It establishes regulations for the management and sustainable forest use of dry forests, the recommended techniques, commitments and responsibilities in the execution of plans, management, forest use and the conservation of its environmental services.	2007	[39]
Standard for the procedure for the Adjudication of State Forest Heritage Lands and Protective Forest and Vegetation	Establish the parameters for the adjudication of lands of the state's forest heritage.	2007	[40]
Ministerial Agreement No. 003	Regulation before the invasion of properties subject to the forest regime	2014	[41]
Standard for Verification and Control Final Destination	Establishes the technical and administrative procedures for the legal verification of forest products	2014	[42]
Forest Seed Standard	Establishes regulations regarding forest seeds in the country.	2004	[43]
Instructions for the measuring of wood	Establishes the measuring techniques for wood transported in vehicles.	2010	[44]
Instructions for the application of tax credit payments for the afforestation program	Establishes the instructions to obtain certification by the Ministry of the Environment to apply as a tax credit, the payments made for afforestation or reforestation programs.	2012	[45]
Operational Manual for the Incentive for Sustainable Forest Management	It establishes the procedures, requirements, beneficiaries and more conditions for the application of incentives for Sustainable Forest Management.	2014	[46]
Operational Manual for the Incentive for the Conservation and Sustainable Use of the Mangrove	It establishes the procedures, requirements and conditions for the application of the incentives for the conservation and sustainable use of the Mangrove.	2014	[47]
National Program of Incentives for the Conservation and sustainable use of Natural Heritage	It integrates the incentive initiatives in a single National Program, seeking a comprehensive intervention in the territory and promoting an improvement in the living conditions of the inhabitants.	2013	[48]
"Socio Bosque" Project Creation	Creation of the "Socio Bosque" Project as a mechanism for the implementation of incentives by the State, through the Ministry of the Environment, for owners of properties covered with native forest, moors and other native plant formations in the country.	2008	[49]
Reform of the "Socio Bosque" Project	Includes plant recovery and ecological cover criteria	2011	[50]
Regulations for promoting forest plantations.	Regulate the registration, approval and execution of felling plans and forest exploitation licenses.	2018	[51]
Reform of the Requirements to grant the Forest Incentive	Amendment to the Instructions to grant the Economic Incentive for Afforestation and Reforestation for commercial purposes.	2014	[52]
Instructional Reform to grant an Economic Incentive for Reforestation for commercial purposes	Amendment to the Instructions to grant the Economic Incentive for Afforestation and Reforestation for commercial purposes.	2016	[53]
Instructions to grant the economic incentive for reforestation and afforestation for commercial purposes	Establishes the procedure for granting incentives to landowners who promote commercial afforestation and reforestation in Ecuador.	2014	[54]

Type of law	Purpose of the Act	Year	Reference
Regulations for the zoning of land for afforestation and reforestation	Regulate the establishment of forest plantations in Ecuador on land available for this purpose.	2013	[55]
Reform to the regulations for the zoning of land for afforestation and reforestation	Reform to the regulations for the zoning of land for afforestation and reforestation.	2013	[56]
Instructions that regulate the preparation, approval and execution of felling programs, forest exploitation licenses and circulation guides for commercial forest plantations	Establish the administrative procedures for the authorization of felling programs, issuance of the corresponding forest exploitation licenses and mobilization guides, coming from commercial forest plantations.	2010	[57]
Technical sheet for commercial reforestation	Document for the presentation of commercial afforestation or reforestation proposals through the Reforestation Incentives Program for commercial purposes.	2013	[58]
Technical Protocol for the registration of the Forest Operator	It establishes the procedure and the technical and operational instruments for the qualification and registration of the Forestry Operator, its renewal, suspension and cancellation of the registration.	2013	[59]
Resolution Inclusion of Persea americana, Hass variety as an incentivized species	It establishes the densities and the respective cost per hectare for the establishment and maintenance of avocado plantations.	2013	[60]
Phytosanitary Measures for Wood Packaging	Establishes the procedures for the certification of raw, elaborated or processed wood packaging in the facilities authorized by the Ecuadorian Service of Agricultural Health	2004	[61]
Provisions for the use of machinery and heavy equipment in mining activities and commercial transport of heavy loads of forest products	Regulates the use of machinery and heavy equipment in mining activities and commercial transport of heavy loads of forest products	2016	[62]
Regulation for Plywood Panels	It establishes the requirements that plywood panels for general use and structural use must meet.	2014	[63]
Procedure for the Certification of Conformity with the INEN Quality Seal	Describes the activities carried out by INEN to apply the certification scheme for products with the INEN Quality Seal.	2015	[64]
Requirements Plywood Boards	It establishes the minimum requirements that plywood panels must meet for certification purposes.	2003	[65]

The information shown in **Table 1** suggests, mainly, that the legislative and executive functions, through their ministries, secretariats, and undersecretaries, are responsible for formulating policies and laws that allow forest management [66]. The main approaches of this regulation can be divided into: i) regulation of forest use, ii) regulation of illegal activities, and, iii) conservation and ecological restoration [67]. Additionally, according to the current National Development Plan, the use of renewable and non-renewable natural resources is promoted.

Regarding local governance, the decentralized autonomous provincial, municipal and parish governments have specific competencies for land use planning and management of their natural resources. This includes the distribution of space, determination of environmental and social impacts, partial studies for conservation, land use and natural resources [68].

Despite the existence of a broad legal framework, for the industrial sector the interests are directed towards productivity and quality. This indicates that aspects such as tax incentives (penalties, exemptions and deductions) for forest use could be emphasized. That is, policies that at the same time promote forest control with sustainable forest management practices.

3.2. Framework and Use of Forest Resources

Forest resources are considered as a source of income for the population. Therefore, these actions generate positive and negative impacts on the environment [69]. Commonly, the human being makes use of natural resources in order to satisfy primary needs such as: food, health and leisure. [70]. Among the political-legal-administrative aspects that Ecuador has taken as a measure is to establish the principal management types and categories of forest: i) National system of protected areas (37.27%); ii) Forest with productive potential (33.91%); iii) Protective Forest (27.01%); Forest plantations (1.81%) [71]. These data show that the management for conservation approach is the main use (64.28%). **Table 2** shows one of the methodologies [67], used to classify the forest area in the country.

Table 2. Forest classification of Ecuador by predominance of ecological region and area. Adapted from [72].

Natural region	Area (km²)	Share (%)	Description
Western Ecuador Moist Forests	40,218	6.27	Found in Colombia and Ecuador. Forests rich in species with high levels of local and regional endemism. Threatened by logging, road construction and colonization.
Northwest Andean Montane Forests	52,937	8.26	Found in Colombia and Ecuador. Exceptionally rich in species with a high proportion of local and regional endemics. Threatened by conversion to agriculture and grasslands, mining operations and logging.
Ecuadorian Dry Forests	22,271	3.47	They have high levels of local and regional endemism. Strongly threatened by logging and grazing.
Guayaquil Flooded Grasslands	3,617	0.56	Found only in Ecuador east of the Daule River
Northern Andean Paramo	58,806	9.17	Found in Colombia and Ecuador. Restricted to high peaks; Species with particular adaptations to cold and dry conditions. Threatened by burning, grazing and conversion to agriculture.
Eastern Cordillera Real Montane Forests	84,442	13.17	Found in Colombia, Peru, and Ecuador. Exceptionally rich in species with a high proportion of local and regional endemism. Strongly threatened by conversion to agriculture and grazing, mining operations, and logging.
Napo Moist Forests	369,847	57.68	Found in Colombia, Peru, and Ecuador. They contain one of the world's richest biotas. It has extraordinary diversity. Oil operations and road construction have caused forest degradation and fragmentation and have facilitated colonization.
Galápagos Islands Xeric Scrub	9,122	1.42	Flora and fauna with a high level of endemism. Threatened by overgrazing, introduction of exotic species and burning.
Total	641,260	100.00	

As shown in **Table 2** the largest of the forest extensions that the country has is found in the humid forests of the Napo with 57.68% including a high biodiversity [73-76]. However, the state also issues forest exploitation permits in this territory prior to the approval of a management plan. With the above mentioned, stakeholders and other state agencies are continually being integrated, with the purpose of developing alternatives that allow an efficient execution of the legal framework.

3.2.1. TFP in Ecuador

Ecuador has different types of forest due to the diversity of climates. Currently, there are cca. 3.6 million of hectares for reforestation, considering a potential of 63 % for productivity [77]. Of the total wood harvested only a small part comes from plantations. These are found mainly in the Ecuadorian highlands (90%), 8% on the coast and only 2% in the Amazon region [78]. Among the main exotic commercial species that have been introduced for plantations are: *Tectona grandis, Eucalyptus globulus, Eucalyptus citriodora, Pinus radiata, Terminalia superba, Gmelina arborea* [77].

3.2.1.1. Uses of the Main Timber Forest Resources

The forestry sector directly creates around 235,000 employments. In addition, exports by the timber industry are increasing income for the economy. Despite the health emergency (COVID-19) which has affected the sector worldwide, the forestry industry has been able to recover through plans and actions taken by authorities to partially restart activities [79].

Tables 3-5 show the main timber species used in Ecuador, divided according to the continental natural regions and their uses: industrial (transformation of raw material), energy (thermal conversion: firewood and coal), protection (conservation), agroforestry (combination with crops) and silvo-pastures (forestry-livestock) [80].

Table 3. List of timber species from Sierra Natural Region. Adapted from [80].

Timber Species in Ecuador						
Climate Type	Scientific Name	Main Uses				
		Industrial	Energetic	Protection	Agroforestry	Silvo-pasture
Dry Mountain Forest	*Eucalyptus saligna*	x	x			
	Eucalyptus grandis	x	x			
	Eucalyptus deglupta	x	x			
	Prunus capuli		x			
	Parkia multijuga	x	x	x	x	x
	Casuarina guisetifolia		x			
	Acacia macrante		x	x	x	x
	Parquia nítida	x		x	x	x
	Cusalpina espinosa		x	x	x	x
	Jacarandá sp.		x	x	x	x
	Clarisla recemosa	x				
	Schumus molle		x	x		
	Cassia Fístula		x	x		

Timber Species in Ecuador						
Climate Type	Scientific Name	Main Uses				
		Industrial	Energetic	Protection	Agroforestry	Silvo-pasture
Humid Montane Forest	*Prosopis intermis*	x	x	x		x
	Tamarindus indica	x	x			x
	Azadirechte indica		x	x		
	Pinus radiata	x				x
	Pinus psuedestrobus	x				x
	Pinus patula	x				x
	Cetrolobium patinesis	x				
	Acacia marguin	x				x
	Ochroma lagopus	x				
	Ochroma piramidale	x				
	Cedrela odorata	x				
	Cedrela Fililis	x				
	Cadelina catenacformis	x			x	
	Triplaris guayaquilensis	x				x
	Tabeuia crysantha	x				
Tropical Moist Forest	*Tabeuia donnel sm.*	x				
	Pseudosamanea guachapele	x				x
	Cordia alliodora	x			x	
	Cariodendrum orionosensis	x			x	x
	Anacardium escelsum	x	x			
	Hiernyma chocoensi	x				
	Pinus Caribea	x				x
	Schizolubium parabybon	x			x	x
	Crotom s.p	x	x			
	Terminaliz iborensis	x			x	x
	Carapa guianensis	x				
	Araucaria angustifolia	x				
	Alnus jarullensis	x				x
	Acacia melanoxilum		x	x		
	Acacia dealbata		x	x		
	Cupresus macrocarpa	x				x
	Cupresus lusitania	x				
	Cedrela rosil	x				
	Telcona stans		x	x		
Humid Montane Forest	*Eucalyptus saligna*	x				
	Eucalyptus grandis	x				
	Eucxalyptus globulus	x				
	Fraxinus americana	x	x			
	Albizzia distachia		x	x	x	
	Grevillea robusta		x	x	x	x
	Juglaris neourotropica	x				
	Gynoxis sp.			x	x	x
	Oreopanax sp.			x	x	x
	Budd leia		x	x		
	Vallea Stipularis			x	x	x
	Polylepsis sp.		x	x	x	x

Table 4. List of timber species from Coast Natural Region. Adapted from [80].

Timber Species in Ecuador						
Climate Type	Scientific Name	Main Uses				
		Industrial	Energetic	Protection	Agroforestry	Silvo-pasture
Tropical Dry Forest	*Swintenia macrophylla*	x				
	Casuarina eguisetifolia		x	x		
	Delonix regia		x	x		
	Minguaitin guianensis	x				
	Leucaena Leucocephala	x	x			x
	Saman samanea	x			x	x
	Tectona grandis	x				
	Spatodea sp.		x	x		

Table 5. List of timber species from Amazon Natural Region. Adapted from [80].

Timber Species in Ecuador						
Climate Type	Scientific Name	Main Uses				
		Industrial	Energetic	Protection	Agroforestry	Silvo-pasture
Very Humid Tropical Forest	*Parkia multijuga*	x			x	x
	Parquia nítida	x			x	x
	Jacarandá capais	x			x	x
	Cordia alliodora	x			x	
	Cariodendrum orionosensis	x			x	x
	Pollalista Kausteril	x			x	
	Crotom s.p	x	x			

Table 6. Main TFP and uses. Adapted from [81,82].

Timber Forest Products	
Type	Product
The primary processing industry:	- Plywood: current, decorative, and marine, laminated, decorative veneers
	- Agglomerates (various thicknesses)
	- MDF boards
	- Sawn wood
	- Pulp and paper
The secondary processing industry:	- Furniture
	- Processors of balsa: panels, glued, planed wood of various dimensions
Construction industry:	- Column processing
	- Beams
	- Wooden trusses
Doors and windows:	- Mouldings
	- Ice cream scoops
	- Tongue depressor
	- Sticks paddles
	- Handicrafts

Ecuador has a high biodiversity of timber trees among which we can highlight *Tectona grandis, Eucalyptus globulus, Eucalyptus citriodora, Pinus radiata, Cordia alliodora, Parquia nitida* and *Swintenia macrophylla*, and which are used by the industry to create products. In addition, **Table 6** shows the

main TFP that have been identified based on the use by type of industry. With the information shown **Table 6**, it can be highlighted that within the most representative timber products for the country, the primary sector industry mainly generates chipboards (25%), plywood boards (11%), paper (6.14%) and wood chips (1.92%), whereas, in the industry of the secondary sector are balsa blocks (23%), furniture (11%), slices and strips (5%) [81, 82].

Wood is an important source of income for households and industries. Considering the progressive increase in the demand for forest resources, the Ecuadorian state has developed actions to control and monitor the movement of wood in the chain of custody. In this context, one of the main initiatives is forest certification, whose purpose is to safeguard the resource and increase its economic value.

3.2.2. NTFP in Ecuador

According to the Food and Agriculture Organization of the United Nations [83], NTFPs are goods of biological origin, other than wood, that come from forests or other areas with the presence of trees, but outside forests. In the country, despite various efforts, there is no adequate regulation to take advantage of these resources in a sustainable way, since the tool applied by the Ministry of the Environment to legitimize this activity is generated at the time of its mobilization through the Circulation Guides and, rarely since its origins [84].

3.2.3. Main NTFP Generated in Ecuador

NTFP in the country play a key role in both urban and rural areas as they generate employment and income for the population. There is a variety of products, which have historically been used by rural communities in areas for: i) food, ii) tools, iii) handicrafts, iv) medicines, v) housing materials and vi) health [85]. **Table 7** shows the main NTFP which have been identified based on the methodology proposed by [86-88].

Table 7. Main NTFP and categories of uses.

Non-Timber Forest Products	
Category	**Main Species**
Food and drinks:	*Bactris gasipaes, Opuntia ficus-indica, Euterpe precatoria* and genus *Pouteria*
Essential oils and ascents:	*Bursera graveolens, Laurus nobilis, Cymbopogon citratus, Eucalyptus citriodora*
Medicines and pharmaceutical principles:	*Uncaria tomentosa, Marsdenia cundurango, Piper aduncum, Phyllanthus niruri*
Toxic, stimulants, natural insecticides:	*Rattlesnake thevetia, Piscidia carthagensis, Erythroxylum coca*
Latex and resins:	*Crotton lechleri, Pinus caribaea*
Colorants and dyes:	*Dactilopious coccus, Bixa orellana*
Fibbers:	*Ceiba trichistandra, Carludovica palmata*
Utensils tools and construction materials:	*Guadua angustifolia*
Mystics, celebrations and rituals:	*Dracroides peruviana, Clusia pallida, Bursera graveolens, Banisteriopsis caapi, Echinopsis pachanoi*
Handicraft:	*Phytelephas aequatorialis*
Ornamental:	Palms of the genus *Chamaedorea*
Forage:	*Prosopis juliflora, Geoffroea spinosa, Acacia macracantha, Guazuma ulmifolia*

Based on the information presented **Table 7**, it should be considered that certain species may have more than one use, for example vegetable ivory (*Phytelephas aequatorialis*). This species is used by local communities, for instance, the use of its leaves, fibers and fruits for the elaboration of handicrafts stands out. Additionally, residues such as sawdust and ground waste are used to make nutritional supplements for livestock [84].

When people refer to NTFP and its main uses, most agree when naming the categories: Food and drinks, medical and pharmaceutical principle. On the other hand, categories such as essential oils, glues, toxic, stimulants, natural insecticides are not usually recognized. Unfortunately, these categories have been underestimated by the industry, despite the existence of countless favorable raw materials but scarcely used.

3.3 The Role of Forest Resources in Ecuadorian Economy

The Ecuadorian economy grew by 5.6% at the end of 2021. This increase was driven by the positive variation of the components of the Gross Domestic Product (GDP), mainly the category of exports related to the use of natural resources such as oil, aquaculture, treated wood products, metallic and non-metallic minerals [89]. Consequently, the production of forest products is based on the provision of native forest and plantations. This has allowed the supply to the national industry for internal consumption and exports [90]. These activities are regulated by current harvesting regulations, mentioned in the section on the legal framework for the management and use of forest resources.

The livelihoods of the population are related to forest management [91]. For instance, rainforests located in the Amazon region (e.g., Brazil, Ecuador, Colombia, Peru, Bolivia and Venezuela) have shown how the forest resource produces high economic income, because their products enter international trade, obtain government royalties, generate income for the sector and fulfill a social function [11].

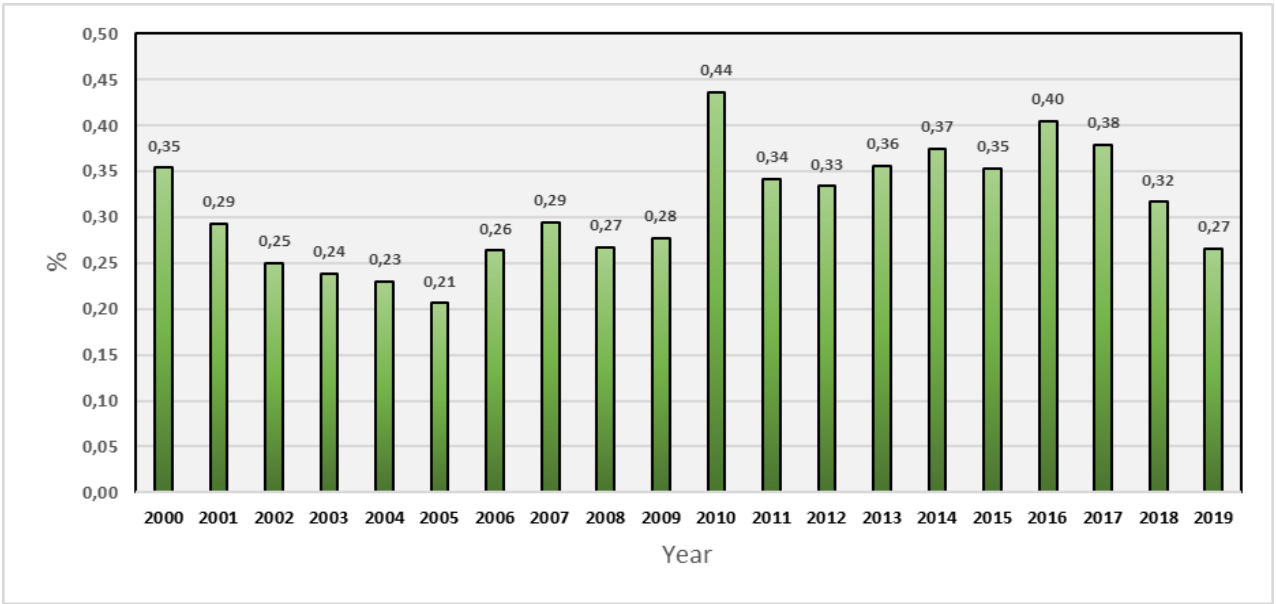

Figure 2. Share of GDP forest income from 2000 to 2019 [92].

Forest rent is expressed as roundwood harvest multiplied by the product of average prices and the region-specific rate [92]. Ecuador has historically generated forest income due to the continuous use of this resource **Figure 2**. The trend of the contribution to the national GDP from 1970 to 1999 has been growing, due to the increase in plantations, mainly in the Amazon region [93]. However, in the year 2000 important changes were included to the forest and conservation law, where control over forest production was increased with the purpose of reducing social and environmental impacts [94]. From the 2000 to the present, this contribution has decreased, with the exception of the year 2010 where forest rents grew (0.44%) due to a greater number of forest exploitation licenses [92]. These annual monetary resources come from forest plantations, native forests and agroforestry systems [95, 84]. The way of commercialization is mainly as raw material, while private owners cede commercial use to third parties, selling standing trees to companies for industrialization [91].

According to information from the Central Bank of Ecuador, the production of wood and derivates is the fifth key industry (demand and supply large quantities of inputs to the rest of the sectors) for the Ecuadorian economy [96]. The Ecuadorian Federation of Exporters (FEDEXPOR), declares that 19 varieties of wood are exported, but *Ochroma pyramidale* and *Tectona grandis* are the most in demand abroad; their main destinations are India, Japan, the United States and China [97].

The super-intendency of companies in Ecuador reports that there are currently 204 companies nationwide dedicated to the extraction of wood, of which 87.3% are located in Guayas, Pichincha, Manabí and Los Ríos provinces [98]. In addition, according to The International Tropical Timber Organization (ITTO), the forestry sector generates around 235,000 direct employments. Most of this employment is generated at the rural level and in small cities where much non-industrialized activity is concentrated [99]. The trade balance of the sector presented a surplus in the analysis period 2016 - 2020 (**Figure 3).** The exports of the sector were on average 73 times higher than imports, this denotes that the sector satisfies internal demand and provides resources abroad.

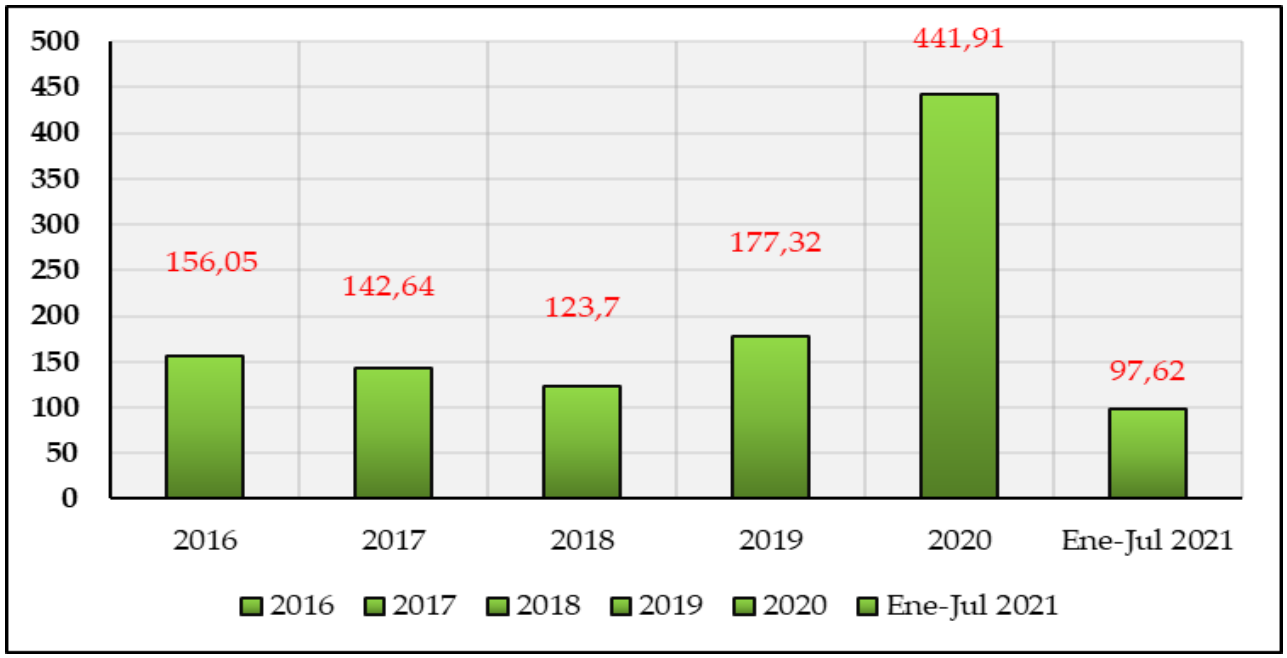

Figure 3. Trade Balance of the Forest sector (Million USD), [92].

In Ecuador's trade balance in the forestry sector, dominate mainly the export of sawn wood, prepared plywood and chipboard, doors and windows and other manufactured wood products [96, 10]. Complementary to this information, through the Free On Board (FOB) incoterm indicator, the export values of wood and its derivatives are shown in **Figure 4**.

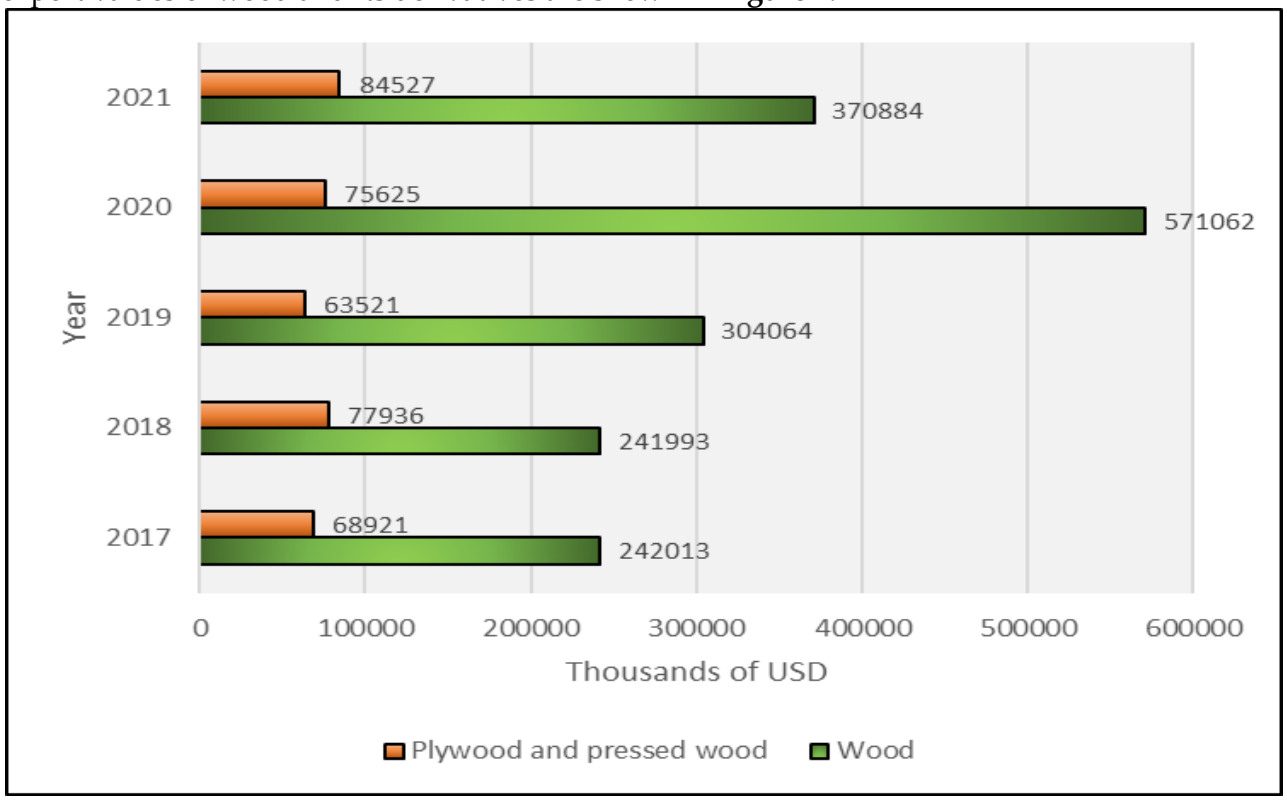

Figure 4. Non-traditional FOB exports [96].

In general terms, this statistical import parameter has had a growing trend. However, in 2021 the economic value of wood exports decreased, mainly due to the drop in international prices due to the health emergency. Additionally, factors such as the cancellation of contracts due to lower demand in destination countries, the cancellation of scheduled international fairs, as well as logistical problems generated by the temporary closure of ports and airports contributed to this trend [96].

The economic contribution of forest resources to the national economy is the consequence of the policies applied with exploitation and conservation approaches. For instance, the market prices of timber products are directly related in the domestic economy to the use of inputs, machinery, infrastructure, fossil fuels and employment levels in the productive sector. Accordingly, the country's forest economic policy is influenced by factors such as: i) international agreements for imports and exports; ii) land use, and iii) the conditions of the forest resource.

The results of this study have been analyzed descriptively and systematically, despite the information gaps and outdated government platforms for forest evaluation and the national forest monitoring system. Therefore, a greater transparency of information could enrich the knowledge base and even a greater application of comparative analyzes of the forestry sector between countries.

4. CONCLUSIONS

Overall, the described concepts and approaches from the role and use of forest resources in Ecuador are divided in exploitation and conservation. The interests of the industries are focused towards productivity and quality, while the government prioritizes forest control policies, international agreements for imports and exports, regulation of land use, management of native forest, reforestation and evaluation of the conditions of the forest resource. Therefore, one of the joint initiatives with Ecuadorian control authorities is forest certification, whose purpose is to increase its economic value and sustainable management practices. In order to increase the participation in national and international markets, the forest sector could be addressed in the potential use of NTFP and not only in TFP.

SUPPLEMENTARY MATERIALS

Not the case.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

APPENDIX

Not the case.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu: *Rolul resurselor forestiere şi utilizarea acestora în Ecuador*

Introducere: *Identificarea beneficiilor generare de păduri necesită evaluarea drepturilor, obligațiilor, stimulentelor şi restricțiilor care promovează o administrare mai bună a pădurilor. Beneficiile relaţionate cu starea pădurilor şi nivelul veniturilor trebuie percepute la un același nivel de importanță de către toți actorii din sector. În ultimele două decenii, relaţia dintre utilizarea şi protecția pădurilor a evoluat prin încorporarea unor indicatori consacrați pentru măsurarea şi urmărirea stării şi diversității biologice a pădurilor. Având în vedere că cea mai mare diversitate se regăsește în ecosistemele tropicale, există un mare potențial pentru generarea de produse lemnoase şi produse accesorii. Cunoașterea realității cu privire la aceste resurse forestiere este importantă în managementul forestier pentru că permite dezvoltarea de analize de natură legală, productivă şi economică pentru identificarea eventualelor beneficii şi a potențialului de utilizare a acestora. Pe această direcție, lucrarea de faţă realizează o sinteză cu privire la managementul forestier şi utilizarea resurselor forestiere în Ecuador.*

Materiale şi metode: *Informațiile cu privire la managementul şi utilizarea resurselor forestiere în Ecuador au fost colectate din articole ştiințifice în limba engleză şi spaniolă precum şi din alte surse cum ar fi planurile de management, informații oficiale emise de guvern şi alte organizații. Căutarea informației s-a realizat prin folosirea unor*

cuvinte cheie cum ar fi ,,management forestier sustenabil", ,,produse lemnoase", ,,produse accesorii", ,,guvernanță forestieră" şi ,,resurse forestiere". Prelucrarea informației a avut la bază analize cantitative şi calitative cu privire la tematicile abordate: i) cadrul legal cu privire la managementul şi utilizarea resurselor naturale, ii) utilizarea resurselor forestiere şi iii) perspectiva economică.

Rezultate şi discuții: *Principalele direcții identificate au fost i) cadrul legal pentru utilizarea resurselor forestiere, ii) cadrul legal pentru combaterea tăierilor ilegale şi iii) conservarea şi ameliorarea ecologică. Interesele sectorului industrial sunt direcționate către productivitate şi calitate. Situația indică faptul că aspecte precum stimulentele financiare şi fiscale pentru utilizarea resurselor forestiere ar putea fi benefice în scopul promovării de politici care contribuie în același timp atât la controlul şi monitorizarea activităților cât şi la practici de management sustenabil. Având în vedere creşterea progresivă a cererii pentru resurse forestiere, Ecuadorul a dezvoltat acțiuni pentru controlul şi monitorizarea fluxului de lemn în lanțul de custodii. În acest context, una dintre inițiativele principale este certificarea forestieră a cărei scop este să protejeze şi să crească valoarea economică a resurselor. Pe de altă parte, în balanța comercială forestieră a Ecuadorului domină exportul de produse ale prelucrării lemnului şi a altor produse finite şi semifinite. Contribuția economică a resurselor forestiere la economia națională este o consecință a politicilor aplicate pentru exploatarea şi conservarea resurselor. De exemplu, în economia autohtonă prețurile de piață pentru produsele forestiere sunt direct relaționate cu utilizarea resurselor, echipamentelor, infrastructurii precum şi cu numărul de locuri de muncă în sectorul productiv. Ca atare, politica economică forestieră a țării este influențată de factori precum: i) acordurile internaționale pentru import şi export, ii) folosința teritoriului şi iii) condițiile resurselor forestiere.*

Concluzii: *Conceptele şi abordările descrise pentru rolul şi utilizarea resurselor forestiere în Ecuador sunt relaționate atât cu exploatarea cât şi cu conservarea resurselor. Interesele industriilor sunt concentrate pe productivitate şi calitate în timp ce guvernul prioritizează politicile de control forestier, acordurile internaționale pentru importuri şi exporturi, legile pentru utilizarea terenurilor, managementul pădurilor naturale, reîmpădurirea şi evaluarea stării resurselor forestiere. Una dintre inițiativele autorităților din Ecuador este certificarea forestieră care are ca scop creşterea valorii economice şi asigurarea de practici forestiere sustenabile. Pentru creşterea gradului de participare pe piețele internaționale, sectorul forestier trebuie să aibă în vedere potențialul utilizării produselor forestiere accesorii.*

Cuvinte cheie: *Management forestier, produse lemnoase, produse accesorii, utilizarea pădurilor, Ecuador.*

REFERENCES

1. Gualsaquí Anrango, N. I., 2018: Determinación de áreas prioritarias para el manejo forestal sostenible en la parroquia Peñaherrera, zona de Intag, noroccidente del Ecuador. Universidad Técnica del Norte, Ibarra-Ecuador, 20-72.
2. Ministerio del Ambiente (MINAM), 2016: La conservación de bosques en el Perú 2011-2016. Conservando los bosques en un contexto de cambio climático como aporte al crecimiento verde. Lima, Perú, Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático, 180.
3. Coad, L., Leverington, F., Burgess, N. D., Cuadros, I. C., Geldmann, J., Marthews, T. R., ... & Hockings, M., 2013: Progress towards the CBD protected area management effectiveness targets. Parks, 19(1), 13-24.
4. Coad, L., Leverington, F., Knights, K., Geldmann, J., Eassom, A., Kapos, V., ... & Hockings, M., 2015: Measuring impact of protected area management interventions: current and future use of the Global Database of Protected Area Management Effectiveness. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1681), (20140281). https://doi.org/10.1098/rstb.2014.0281
5. Stolton, S., & Dudley, N., 2016: METT handbook: A guide to using the Management Effectiveness Tracking Tool (METT). Woking: WWF-UK.

6. Geldmann, J., Coad, L., Barnes, M. D., Craigie, I. D., Woodley, S., Balmford, A., ... & Burgess, N. D., 2018: A global analysis of management capacity and ecological outcomes in terrestrial protected areas. Conservation Letters, 11(3), (e12434). https://doi.org/10.1111/conl.12434
7. Nolte, C., & Agrawal, A., 2013: Linking management effectiveness indicators to observed effects of protected areas on fire occurrence in the Amazon rainforest. Conservation Biology, 27(1), (155-165). https://doi.org/10.1111/j.1523-1739.2012.01930.x
8. Hynynen, J., 2011: Conceptos básicos para la modelación del crecimiento forestal. Revista Recursos Naturales y Ambiente; Número 64 (Diciembre 2011), (1659-1216,22-27). Available online at: https://repositorio.catie.ac.cr/handle/11554/7075
9. Aguirre-Calderón, O. A., 2015: Manejo forestal en el siglo XXI. Madera y bosques, 21, (1405-0471), 17-28.
10. Rivadeneira Navarrete, J. D., 2016: El rol de la política pública para alcanzar la sostenibilidad en la extracción del recurso forestal maderable en el Ecuador, Pontificia Universidad Católica Del Ecuador (PUCE), Quito-Ecuador, 25-101.
11. Izko, X., & Burneo, D., 2003: Herramientas para la valoración y manejo forestal sostenible de los bosques sudamericanos. Oficina Regional para América del Sur de la UICN, Quito-Ecuador, 1-9, 9978424709.
12. Cubbage, F., Diaz, D., Yapura, P., & Dube, F., 2010: Impacts of forest management certification in Argentina and Chile. Forest Policy and Economics, 12(7), 497–504. https://doi.org/10.1016/j.forpol.2010.06.004
13. Palacio, W., & Jaramillo, N. (2001). Riqueza florística y forestal de los bosques tropicales húmedos del Ecuador e implicaciones para su manejo. Recursos Naturales y Ambiente, 36, (1659-1216).
14. Peláez, E. J. J., 2012: El manejo forestal en México: estado actual y perspectivas. In: Estado de los bosques de México., Consejo Civil Mexicano Para La Silvicultura Sostenible A.C., Mexico D.F., 69.
15. Millennium Ecosystem Assessment (MA)., 2005: Ecosystems and Human Well-being: A Framework for Assessment. Island Press, Washington, DC. Available online at: http://www.unep.org/maweb/en/Framework.aspx (Accessed on 23/02/2022).
16. Haines-Young, R., & Potschin, M., 2010: Proposal for a common international classification of ecosystem goods and services (CICES) for integrated environmental and economic accounting. European Environment Agency, 30.
17. Harrison, P. A., Berry, P. M., Simpson, G., Haslett, J. R., Blicharska, M., Bucur, M., ... & Turkelboom, F., 2014: Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosystem services, 9, 191-203. https://doi.org/10.1016/j.ecoser.2014.05.006
18. De Beer, J.H. & M. McDermott., 1989: The economic value of non-timber forest products in Southeast Asia: with emphasis on Indonesia, Malaysia and Thailand, The Netherlands Committee for UICN, Amsterdam, 19906709589, 197.
19. Food and Agriculture Organization (FAO), 2005: Anuario de productos forestales 2003. Colección FAO: Montes No. 38. Colección FAO, Estadística no. 184. FAO, Roma. 243.
20. Segura, D., Jiménez, D., Chinchero, M., Iglesias, J., & Sola, A., 2015: Evaluación nacional forestal del ecuador, un proceso en construcción hacia el monitoreo de los bosques y la biodiversidad. In XIV congreso forestal mundial, Quito, Ecuador, -11 de septiembre de 2015, 1-7.
21. Gavilanes Montoya, A. V., Castillo Vizuete, D. D., Ricaurte Yepez, C. B., & Marcu, M. V., 2019: Known and newly documented uses of rainforest plant species in the Pastaza region, Ecuador.

Bulletin of the Transilvania University of Brasov, Series II. Forestry, Wood Industry, Agricultural Food Engineering, 12(1).

22. SENPLADES, E., 2011: Guía de contenidos y procesos para la formulación de Planes de Desarrollo y Ordenamiento Territorial de provincias, cantones y parroquias; Documento de trabajo v1.1; Senplades, Ecuador Available online at: http://www.gobiernogalapagos.gob.ec /wp-content/uploads/downloads/2013/08/SENPLADES_Guia_Metodologia_Planes_Desarrollo_Ordenamiento_Territorial.pdf
23. Ministerio del Ambiente del Ecuador (MAE), 2015: Sistema de Clasificación de los Ecosistemas del Ecuador Continental. Subsecretaría de Patrimonio Natural, Quito, in press. (accessed on 13/01/2022).
24. De la Torre, L., Navarrete, H., Muriel, P., Macía, M. J., & Balslev, H., 2008: La diversidad de ecosistemas en el Ecuador. In: Enciclopedia de las plantas útiles del Ecuador, Herbario QCA & Herbario AAU, Quito, Ecuador, 28-38.
25. Carrasco, A., Cárdena, C., & Crespo, E., 2012: Catálogo de productos maderables y empresas certificadas en el Ecuador: un apoyo para las compras públicas responsables. TRAFFIC Sudamérica. Available online at: https://www.traffic.org/site/assets/files/6449/catalogo-de-productos-maderables.pdf
26. Instituto Nacional de Estadísticas y Censos, 2015: Agenda de desarrollo 2030 de la República del Ecuador. Available online at: http://www.ecuadorencifras.gob.ec/vida-de-ecosistemas-terrestres/
27. Ministerio del Ambiente, 2000: Estrategia para el Desarrollo Forestal Sustentable del Ecuador. Ministerio del Ambiente. Available online at: http://www.tecnologiaslimpias.cl/ecuador/docs/forestal.pdf
28. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The PRISMA Group, 2009: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PloS Med. 6 (7), e1000097. https://doi.org/10.1371/journal.pmed1000097 .
29. Arce, R., 2019: Aproximaciones a la filosofía forestal de la sustentabilidad del manejo forestal en el Perú. Revista Forestal del Perú 34(2), (2523-1855) 113-131. DOI: http://dx.doi.org/10.21704/rfp.v34i2.1322
30. Asamblea Constituyente, 2008: Constitución de la República del Ecuador. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 449.
31. Asamblea Constituyente, 2017: Código Orgánico del Ambiente. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 983.
32. Asamblea Constituyente, 2014: Ley Orgánica de Incentivos a la Producción y Prevención del Fraude Fiscal. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 405.
33. Asamblea Constituyente, 2003: Texto Unificado de Legislación Secundaria, Medio Ambiente. Quito: Tribunal Constitucional del Ecuador. Decreto Ejecutivo Nro, 3516.
34. Asamblea Constituyente, 2017: Ley Orgánica para la reactivación de la economía, fortalecimiento de la dolarización y modernización de la gestión financiera. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 150.
35. Asamblea Constituyente, 2018: Ley orgánica para el Fomento Productivo, Atracción de Inversiones, Generación de Empleo y Estabilidad y Equilibrio Fiscal. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 309.
36. Función ejecutiva, 2015: Normas para el Manejo Forestal Sostenible de los Bosques Húmedos. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 272.

37. Función ejecutiva, 2010: Procedimientos para Autorizar el Aprovechamiento y Corta de Madera. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 164.
38. Función ejecutiva, 2006: Normas para el Manejo de los Bosques Andinos. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 416.
39. Función ejecutiva, 2007: Normas para el Manejo Forestal Sustentable de Bosque Seco. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 157.
40. Función ejecutiva, 2007: Norma para el procedimiento para la Adjudicación de Tierras del Patrimonio Forestal del Estado y Bosque y Vegetación Protectores. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 265.
41. Función ejecutiva, 2014: Acuerdo Ministerial N°003. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 195.
42. Función ejecutiva, 2014: Norma para la Verificación y Control Destino Final. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 049.
43. Función ejecutiva, 2004: Norma de Semillas Forestales. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 269.
44. Asamblea Constituyente, 2010: Instructivo Cubicación de Madera. Quito: Tribunal Constitucional del Ecuador, Available online at: http://ecuadorforestal.org/wp-content/uploads/2010/05/Instructivo-Cubicaci%C3%B3n-de-Madera.pdf
45. Función ejecutiva, 2012: Instructivo aplicación crédito tributario pagos programa forestación. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 785.
46. Función ejecutiva, 2014: Manual Operativo para el Incentivo al Manejo Forestal Sostenible. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 187.
47. Función ejecutiva, 2014: Manual Operativo para el Incentivo a la Conservación y Uso Sustentable del Manglar. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 198.
48. Función ejecutiva, 2013: Programa Nacional de Incentivos a la Conservación y uso sostenible del Patrimonio Natural. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 131.
49. Función ejecutiva, 2008: Creación Proyecto Socio Bosque. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 482.
50. Función ejecutiva, 2011: Reforma al Proyecto Socio Bosque. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 130.
51. Asamblea Constituyente, 2018: Normativa para el impulso de plantaciones forestales. Quito: Tribunal Constitucional del Ecuador. Acuerdo ministerial Nro, 010. https://ecuadorforestal.org/wp-content/uploads/2018/07/Acuerdo-Ministerial-010..pdf
52. Función ejecutiva, 2014: Reforma Requisitos para otorgar el Incentivo Forestal. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 374.
53. Función ejecutiva, 2016: Reforma Instructivo para otorgar Incentivo Económico a la Reforestación con fines comerciales. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 716.
54. Función ejecutiva, 2014: Instructivo para otorgar el incentivo económico para la reforestación y forestación con fines comerciales. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 035.
55. Función ejecutiva, 2013: Normativa para la zonificación de tierras para forestación y reforestación. Quito: Tribunal Constitucional del Ecuador. Registro oficial Nro, 884.

56. Función ejecutiva, 2013: Reforma a la normativa para la zonificación de tierras para forestación y reforestación. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 258.
57. Función ejecutiva, 2010: Instructivo que regula la elaboración, aprobación y ejecución de los programas de corta,licencias de aprovechamiento forestal y guias de circulación de plantaciones forestales comerciales. Quito: Tribunal Constitucional del Ecuador. Acuerdo ministerial Nro, 327.
58. Subsecretaría de Producción Forestal, 2013: Ficha técnica para la reforestación comercial. Quito: Tribunal Constitucional del Ecuador. Resolución Nro, 001.
59. Subsecretaría de Producción Forestal, 2013: Protocolo Técnico para el registro del Operador Forestal. Quito: Tribunal Constitucional del Ecuador. Resolución Nro, 003.
60. Subsecretaría de Producción Forestal, 2013: Inclusión del Aguacate (Persea americana), variedad Hass como especie incentivada. Quito: Tribunal Constitucional del Ecuador. Resolución Nro, MAGAP-SPF-2013-0146-R.
61. Subsecretaría de Producción Forestal, 2004: Medidas Fitosanitarias para Embalaje de Madera. Quito: Tribunal Constitucional del Ecuador. Registro Oficial Nro, 248.
62. Subsecretaría de Producción Forestal, 2016: Disposiciones para el uso de maquinaria y equipo pesado en la actividad minera y transporte comercial de carga pesada de productos forestales. Quito: Tribunal Constitucional del Ecuador. Acuerdo Ministerial Nro, 002.
63. Función ejecutiva, 2014: Reglamento Técnico Ecuatoriano Tableros de Madera Contrachapado. Quito: Tribunal Constitucional del Ecuador. RTE INEN Nro, 243.
64. Función ejecutiva, 2015: Procedimiento para la Certificación de Conformidad con Sello de Calidad INEN. Quito: Tribunal Constitucional del Ecuador. RTE INEN Nro, VC-PR-20.
65. Función ejecutiva, 2003: Requisitos Tableros Contrachapado. Quito: Tribunal Constitucional del Ecuador. NTE INEN Nro, 900:2003.
66. Food and Agriculture Organization (FAO), 2009: Contribución de los Criterios e Indicadores Hacia la Sostenibilidad del Manejo Forestal: el Caso de Ecuador, Available online at: http://www.fao.org/tempref/docrep/fao/011/k4760s/k4760s00.pdf (accessed on 27/01/2022).
67. Ministerio del Ambiente del Ecuador (MAE), 2011: Gobernanza Forestal en el Ecuador 2011. Quito, Ecuador. Available online at: http://flegt.info/wp-content/uploads/2013/02/Gobernanza-Forestal-en-el-Ecuador.pdf (accessed on 07/02/2022).
68. Gobiernos Autónomos Descentralizados, 2011: Código Orgánico de Organización Territorial, Autonomía y Descentralización (COOTAD), Ecuador, (accessed on 07/02/2022).
69. Orellana Salas, J. A., & Lalvay Portilla, T. D. C., 2018: Uso e importancia de los recursos naturales y su incidencia en el desarrollo turístico. Caso Cantón Chilla, El Oro, Ecuador. Revista interamericana de ambiente y turismo, 14(1), 65-79. http://dx.doi.org/10.4067/S0718-235X2018000100065
70. Vega, R. A., & Vivas, X. M., 2007: El turismo como motor de crecimiento económico. Anuario jurídico y económico escurialense, (40), 677-710, (1133-3677)
71. Castillo Vizuete, Danny Danniel; Gavilanes Montoya, Alex Vinicio, 2020: Challenges faced by the ecuadorian forests and forest industry. Revista Pădurilor, Vol. 135(4), 001-056.
72. Galindo, G.,2011: Recopilación de información Ministerio del Ambiente del Ecuador.
73. Quisiyupanqui, R., & Natividad, M., 2013: Caracterización de fuentes semilleras para uso sostenible y conservación de recursos forestales de los bosques andinos de Loja, Ecuador, CATIE, Turrialba, Costa Rica.

74. Izko, X., & Mejía, L., 1998: Ordenamiento de los recursos forestales, desarrollo sostenible y pobreza rural en el Ecuador. In Programa Regional de Bosques Nativos Andinos. PROBONA, Quito, Ecuador (lil-347693), 96-96.
75. Grijalva, J., Checa Rivas, X. P., Ramos Veintimilla, R., Barrera, P., Vera, R., & Sigcha Morales, F. A., 2016: Estado de los recursos genéticos forestales en Ecuador. Quito, Ecuador: INIAP, Estación Experimental Santa Catalina, Programa Nacional de Forestería, 978-9942-21-116-8. Available online at: http://repositorio.iniap.gob.ec/handle/41000/2742
76. Palacios, W. A., & Freire, J. L., 2004: Recursos forestales y territorios indígenas en Ecuador. In MEMORIAS DEL PRIMER ENCUENTRO ANDINO DE DERECHO FORESTAL AMBIENTAL CON ENFOQUE COMUNITARIO, Quito, Ecuador, 13-14 /10/2004, 120.
77. Burgos, B., & Delgado, D., 2018: Estudio económico del comportamiento de la madera en el Ecuador en los últimos años. 2009-2017. Observatorio Iberoamericano del Desarrollo Local y la Economía Social, (25).
78. Vlosky, R. P., & Aguilar, F. X., 2005: Productos forestales en Ecuador: análisis y recomendaciones para su desarrollo. Revista Alternativas, 6(8), 22-27. Available online at: https://link.gale.com/apps/doc/A157838762/IFME?u=anon~9b07849b&sid=googleScholar&xid=183ee33c (accessed on 18/02/2022)
79. Naveda, N., 2020: EXPORTACIÓN DE PRODUCTOS FORESTALES MADERABLES Y NO MADERABLES. Comunidad Todo Comercio Exterior Ecuador. Available online at: https://comunidad.todocomercioexterior.com.ec/profiles/blogs/exportaci-n-de-productos-forestales-maderables-y-no-maderables (accessed on 04/03/2022).
80. Ministerio del Ambiente del Ecuador, (MAE), 2013: SISTEMA NACIONAL DE CONTROL FORESTAL. Available online at: https://www.ambiente.gob.ec/wp-content/uploads/dowlands/2015/07/CONTROL-FORESTAL.pdf (accessed on 13/03/2022).
81. Ministerio del Comercio Exterior e Inversiones, 2019: Available online at: Gob.ec. http://logistica.produccion.gob.ec/wp-content/uploads/2019/07/PLTS-MADERA.pdf (accessed on 16/02/2022).
82. Cámara de Comercio de Quito, 2012: Relación comercial con el Mercosur. Quito, Ecuador.
83. Food and Agriculture Organization (FAO), 2020: Productos forestales no madereros. Available online at: http://www.fao.org/forestry/nwfp/6388/en/ (accessed on 17/03/2022).
84. Arias, E., Robles, M., Romero, M., Villegas, T., Tene, W., Galindo, G., ... & Miranda, A. (2010). Aprovechamiento de Recursos Forestales del Ecuador. Servicios. ambiente. gob. ec. Periodo., Available online at: Available online at: http://www.itto.int/files/user/pdf/PROJECT_REPORTS/PD%20406_06_%20Forest%20Harvesting%20in%20Ecuador%202010%20offenses%20and%20forfeiture.pdf (accessed on 13/03/2022).
85. Valencia Zambrano, G. L., 2022: Empleo de productos forestales no maderables, como parte de la cultura rural, recinto Pan y Agua, Manabí, Jijpijapa. UNESUM. Universidad Estatal de Manabí, Manabí, Ecuador, 64.
86. Food and Agriculture Organization (FAO), 1996: Desarrollo de los productos forestales no maderables en América Latina y el Caribe. Oficina Regional de la FAO para América Latina y el Caribe. Santiago de Chile.
87. Food and Agriculture Organization (FAO), 2001: Evaluación de los recursos forestales mundiales 2000. Informe Principal.
88. Food and Agriculture Organization (FAO), 2008: Productos forestales no maderables, Available online at: www.fao.og/forestry/site/6388/es

89. Banco Central del Ecuador (BCE), 2021: Cuentas Nacionales Trimestrales, Available online at: https://contenido.bce.fin.ec/home1/58esis58ías58as/cntrimestral/CNTrimestral.jsp (accessed on 05/03/2022).
90. Barrantes, G., Chaves, H., & Vinueza, M., 2010: El bosque en el Ecuador. Una visión transformada para el desarrollo y la conservación. EC. (accessed on 18/01/2022).
91. De Jong, W., Pokorny, B., Sabogal, C., Louman, B., & Stoian, D., 2008: Antecedentes, realidad y oportunidades del manejo forestal comunitario en América Latina. El manejo forestal comunitario en América Latina: experiencias, lecciones aprendidas y retos para el futuro. CIFOR, CATIE. Belem, Brazil, 33-74.
92. World Bank Group., 2022: Rentas forestales (% del PIB) – Ecuador | Data. Rentas Forestales (% Del PIB) – Ecuador. Available online at: https://datos.bancomundial.org/indicador/NY.GDP.FRST.RT.ZS?locations=EC (accessed on 21/01/2022).
93. Saquinga Sangucho, W. S., 2022: Dimensión de la globalización, crecimiento económico y recursos naturales del Ecuador: Una estimación causal no lineal. Universidad Técnica de Ambato, Ecuador, Available online at: https://repositorio.uta.edu.ec/jspui/handle/123456789/34365
94. Navarro, G., Del Gatto, F., & Schroeder, M., 2009: Sistema Ecuatoriano Tercerizado de Control Forestal, Economía, Política y Gobernanza del Ordenamiento de Recursos Naturales Publicación no. 3, Boletín técnico no. 32, CATIE: Turrialba, ISBN 978-9977-57-491-2
95. Añazco, M., Morales, M., Palacios, W., Vega, E. & Cuesta A., 2010: Sector Forestal Ecuatoriano: propuestas para una gestión forestal sostenible. Programa Regional ECOBONA-INTERCOOPERATION. Quito. Serie Investigación y Sistematización No. 8.
96. Banco Central del Ecuador., 2022: Información estadística mensual. In Boletin IEM (2040th ed., p. 125). Quito: Gestión de Información. Available online at: https://contenido.bce.fin.ec/documentos/PublicacionesNotas/Catalogo/IEMensual/m2040/IEM2040.pdf
97. FEDEXPOR., 2021: Expordata Online – Fedexpor. Available online at: https://www.fedexpor.com/expordata-online/
98. Supercias., 2021: Superintendencia de 58compañías, valores y seguros. Resolución No. 97.1. 7.3. 0011, Doctrina, 65.
99. Blaser, J., Poore, D., Chandrasekaran, C., Hirakuri, S., Johnson, S., Rubin, H., & Sobral Filho, M., 2016: Status of Tropical Forest Management 2015. Summary Report. International Forestry Review, 8(3), 372-374.