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Expanding Exotic Forest Plantations and Declining Rural Populations in La Araucanía, Chile

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Abstract: Chile has embraced the expansion of monoculture forest plantations of exotic Monterey pine and eucalyptus as part of its development strategy. While forestry is considered financially successful and meets sustainability objectives, the increase in forest plantations across southern Chile has received harsh critiques for exacerbating conflict over Indigenous land rights, producing negative environmental outcomes, and increasing poverty and inequality. There are also claims that forest plantation expansion has led to an abandonment of the countryside. Migration is viewed as a result of the socioeconomic challenges that forest plantations produce at the local level; however, the linkages have not been explored. We examine the linkages between forest plantations and migration through two questions: Is there a relationship between forest plantation cover change and out-migration from rural areas? If so, what are the factors that explain this process? We use a difference-in-differences method analyzing panel data from the Chilean census and from CONAF, the Chilean National Forest Corporation, complemented by interviews, mapping workshops, and focus groups to answer these questions. Results indicate a statistically significant relationship between expanding forest plantations and population decline in rural areas. Qualitative data show that this expansion led to displacement of residents, declines in employment opportunities, and agriculture difficulties.

Keywords: forest plantations; migration; population decline; extractivism; political ecology

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1. Introduction

Throughout much of the 20th century, Chile has embraced the expansion of monoculture forest plantations of exotic Monterey pine *(Pinus radiata* D. Don*)* and eucalyptus *(Eucalyptus globulus* Labill and *Eucalyptus nitens* H. Deane and Maiden) as part of its development strategy. Since the 1970s, planted forests, particularly prevalent in the country's south, have increased from 400,000 hectares (ha) in 1974 to around 3 million ha in 2019 [1]. This expansion has been incentivized through the implementation of Decree Law (DL) 701, which subsidizes up to 75% of the costs of forestation and provides meaningful corporate tax incentives. Today, the industry is valued at 6 billion USD [1]. While the forestry industry is considered by some to be successful for its steady profits and potential for meeting sustainability objectives through the increase in carbon capture, the expansion of forest plantations across southern Chile has received critiques for exacerbating conflict over the longstanding struggle for Indigenous land rights [2–5], negative environmental outcomes such as water scarcity [6–9], and increasing poverty and inequality [10–13]. Among the other sociospatial and socioeconomic consequences described in the literature and by activists is the argument that forest plantation expansion has led to an abandonment of the countryside in places with high concentrations of plantations, countering industry claims that forest plantations would bring increased job security and prevent out-

migration [1,2,10,14,15]. In this body of work, out-migration is viewed as the result of the socioeconomic challenges that forest plantations produce at the local level. Research has shown that Chilean *comunas* (Political division similar to the U.S. "county." Chilean regions are divided into smaller *comunas*.) with greater extensions of forest plantations have higher rates of poverty [11,12]. These studies have hypothesized that higher rates of poverty could lead to out-migration; however, there is no agreement on this point in the literature. While Andersson and colleagues found no relationship between forest plantations and migration, Cerda and colleagues, using a different method, found the opposite [11,13]. Other research argues that out-migration is the result of local unemployment experienced as a result of forest plantation expansion [1,10,15]. For example, according to Montalba and colleagues [10], in their study of one of the most heavily afforested *comunas* in the region of La Araucanía, Lumaco, out-migration occurs when people are forced off the land and lose access to the agricultural employment opportunities displaced by the forest plantations. These studies present contradictory results and a differing hypothesis regarding the prevalence and causes of out-migration due to forestry industry expansion and have not examined out-migration exclusively.

The question of the relationship between out-migration and the expansion of forest plantations is part of a larger discussion about the environmental and agrarian drivers of migration (In this article, we use the term "out-migration" to refer specifically to the process of emigration or leaving a community of origin. The term "migration" refers to the general process of mobility from sending communities to receiving communities and encompasses both emigration and immigration.) [16–19]. Within this literature, work dedicated to specifically exploring the linkages between native and planted forests and migration has produced diverse and geographically specific findings. Research elsewhere in Latin America finds that forests attract migrants—often referred to as colonists—in search of farmland, which can result in the reduction of forest cover [20,21]. Meanwhile, other work in the same region shows that out-migration of rural residents is linked to forest recovery or expansion as agricultural activities are abandoned, while still others find no link between the two processes [22–25]. Forest gain and forest loss varies between countries and geographical contexts [26,27]. While this literature tends to focus on tropical, native forests, and reforested areas, fewer studies have examined extractivist, non-native forest plantations as potential drivers of migration. Forest plantations are extractivist because they exploit natural resources for both domestic use and for export. Extractivism, a key aspect of agrarian change in Latin America today, is linked to land grabbing, reduced access to land, shifting livelihoods, wage compression, and unemployment, all of which are potential drivers of out-migration from rural spaces [28–30]. We view non-native forest plantations in these same terms where non-native eucalyptus and Monterey pine are valued both in Chile and for export. While researchers have begun to detail the relationship between extractivism and migration, there is still little known about how extractivism may lead to out-migration and our study adds to this growing body of work all of which are potential drivers of out-migration from rural spaces [31,32].

The objective of this article is to advance understandings about the linkages between the negative socio-economic consequences of the forestry industry and out-migration, and to do so, we explore the following questions: Is there a relationship between exotic forest plantation cover change and out-migration from rural areas? If so, what are the factors that explain this process? We address these questions using a mixed methods approach [33]. The first question is explored through a statistical examination of population loss in rural communities in La Araucanía, a region in Chile (see Figure 1) where forest plantations make up the principal land use [34]. We then use a qualitative case study to enrich and deepen our quantitative findings.

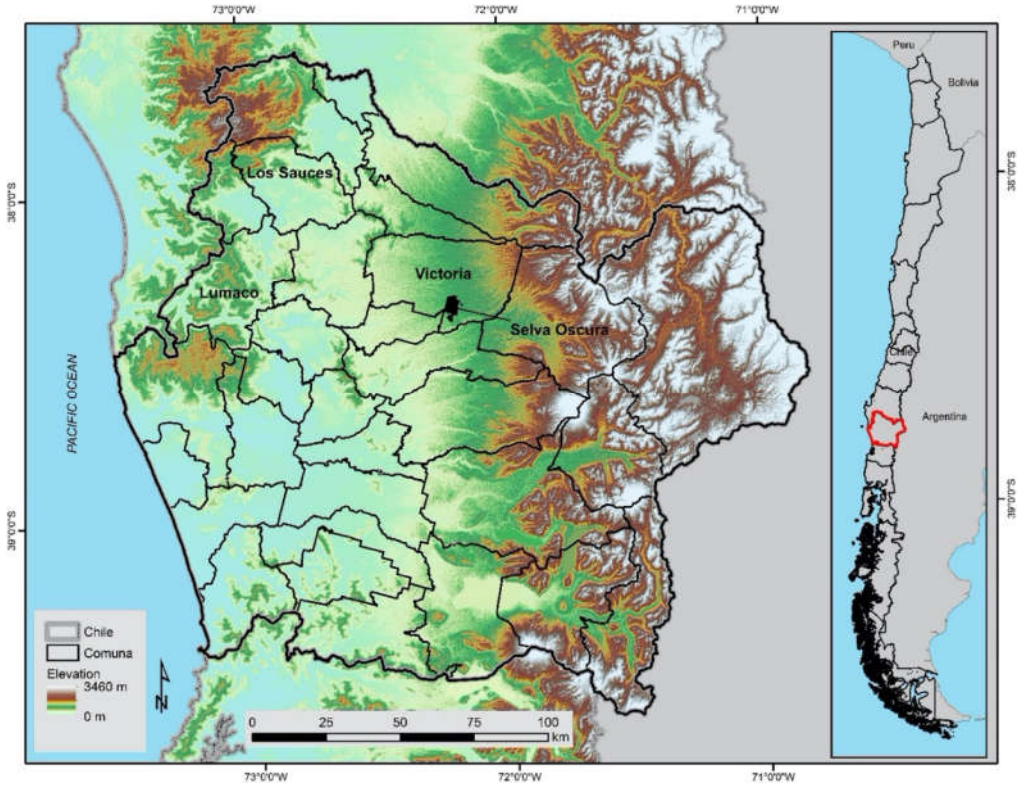

Figure 1. The Study Region, La Araucanía, Chile, and its *comunas*. Place names mentioned in the text are labeled. Data sources: Political boundaries from Infraestructura de Datos Geospaciales of Chile and ASTER GDEM from United States Geological Survey (USGS) AppEEARS. Created by Molly H. Polk.

The study of the environmental drivers of out-migration, and in particular, the question of whether the expansion of the forestry industry leads to migration poses specific challenges. Migration scholars have long warned against identifying any unique "cause" as the underlying motive for an individual's migration [16,35]. The decision to migrate is a complex one that generally involves weighing multiple factors unfolding across scales. For example, push factors might include unemployment, a failed harvest, or damage after a storm, while pull factors in a destination might be educational opportunities, availability of employment, or family reunification [35,36]. The decision could be individual or could likely be the result of a household decision-making strategy to optimize benefits. Overarching political and economic contexts, along with intersecting systems of oppression—gender, race, disability, class, and sexual orientation—also shape migration. In the specific context of rural migration in Chile, research has identified the search for education and job opportunities as key drivers [37,38]. Thus, when we ask the question of whether forest plantation expansion leads to out-migration, as scholars and activists have claimed, we must proceed with caution. A statistical relationship may be identified, however, as the literature suggests, the context may be more complex. This article takes a migration studies approach to understanding out-migration from areas with important concentrations of forest plantations in order to not only measure the impact that the growth of plantations have had on local population dynamics, but also to describe the likely more complex mechanisms driving migration decisions, as suggested by the literature [16,18].

2. Study Region and Methods

In order to understand the linkages between forest plantation expansion and out-migration we conducted a mixed methods study in La Araucanía, Chile. In the following

section we first describe the study area and then detail each of the quantitative and qualitative approaches separately.

2.1. Study Region

The study takes place in La Araucanía, Chile, also known as the Araucanía Region**.** It is located approximately 600 km south of the Chilean capital, Santiago, and is bordered by the Pacific Ocean to the west and the Andes mountains and Argentina to the east. The region possesses a temperate oceanic climate, with average precipitation ranging from 1500 mm to 2500 mm a year, typically falling between May and October. The average annual temperature is 12.5 °C. We selected La Araucanía because it is one of the regions most impacted by the expansion of exotic forest plantations in Chile. For example, La Araucanía has a total of 632,289 ha of plantations, compared to 275,196 ha of native forest [39]. The plantations represent 20% of the total area in La Araucanía. In some *comunas* in the region, forest plantations dominate the rural landscape; in Lumaco, for example, 61% of the land is covered by forest plantations, while in nearby Los Sauces, 55% is covered by forest plantations [39]. The majority of forest plantations are located on large estates [16]. The primary agricultural products of the region, in addition to cellulose, include wheat, oats, rapeseed, lupine, and increasingly, fruits, and berries. Smallholder agricultural production of these products is generally oriented to market production, while a portion of wheat, oats, and grasses goes to family consumption as well. At the time of the last agricultural census in 2007, the region accounted for 30% of the country's family gardens used for family consumption or marketed at small scale.

The political region of La Araucanía is divided into 32 *comunas*, which are further divided into hundreds of smaller units; for urban zones, cities, and for rural zones, these units are *localidades*. For consistency and because translation could introduce confusion, we use the Spanish terms for the Chilean political divisions. La Araucanía is considered to be a rural region, with 29% of its population living in rural areas and 25.4% of the rural population experiences multidimensional poverty [40]. La Araucanía is Mapuche indigenous ancestral territory and is home to a long struggle for Mapuche land rights, which is complicated by the existence of the forestry industry in the region. Indigenous groups maintain that their territory has been infringed upon by forestry corporations and because plantations cover large tracts of land, many have called for their redistribution. A full exploration of these struggles is beyond the scope of this research, but we note here this ongoing struggle to provide context. Land conflicts in the region unfold in a context of highly unequal tenure: According to ODEPA,the Chilean Office for Agrarian Research and Policy [34], 71.8% of farms are smaller than 20 ha, but are equivalent to 9.95% of agricultural land, while farms of more than 100 ha make up 6.3% of the total and represent 71.7% of the total of agricultural land.

2.2. A Mixed-Methods Approach to Understanding Out-Migration and Forest Plantation Expansion

This study is based on a mixed methods approach to understanding the linkages between forest plantation expansion and out-migration. A mixed methods approach integrates quantitative and qualitative methods in order to "minimize the limitations of both approaches," and to furnish a more complete understanding of a research problem [33]. Where quantitative methods measure the extent of a problem, qualitative methods provide detail to help interpret quantitative findings and also provide access to people's lived experiences [41]. Mixed methods are often applied with the goal of confirming, deepening, and explaining quantitative results [33]. Our rationale for using a mixed methods approach is based on these benefits, and also aligns with our migration studies framing that conceptualizes migration as a complex process. Indeed, over the last decades, migration studies has experienced an epistemological shift that has placed increased value on the qualitative study of migration in light of the limitations of purely quantitative studies that are unable to capture migration as an ongoing process occurring across space and time

[42,43]. Thus, our mixed methods approach allows us to both identify the relationship between forest plantation expansion and out-migration in the region, while also describing the nature of this relationship and triangulating findings in turn, bolstering their validity [33].

We implemented a convergent mixed methods design in which the quantitative and qualitative data are collected and analyzed in parallel and in which the same or similar variables or concepts are analyzed. The quantitative study samples *localidades* (rural localities) in La Araucanía, whereas the qualitative case study covers a smaller zone of La Araucanía (see Figure 2). The difference in sampling schemes used in our qualitative and quantitative approaches is typical of mixed methods and reflects the distinct goals of each approach [33].

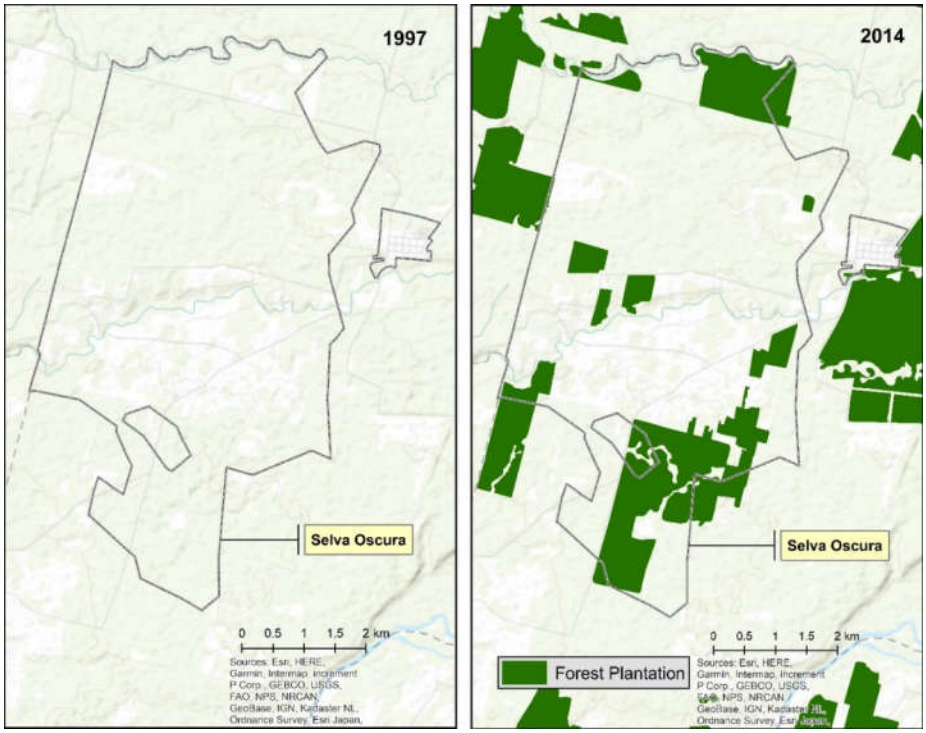

Figure 2. Forest plantations in and around Selva Oscura in 1997 (**left**) and 2014 (**right**). Forest plantation data source: CONAF, the Chilean National Forest Corporation. Created by Molly H. Polk.

2.3. Quantitative Data and Methods

There are limited quantitative data available on internal migration in Chile. While internal migration data is available from the Chilean Census of Population and Housing (hereby referred to as "the census"), it is not detailed enough for us to measure out-migration from rural areas. The census asks whether or not an individual has resided in their current *comuna* for the last five years, and if not, to name the previous *comuna* of residence. *Comunas* consist of both cities and rural areas. Thus, we may identify the *comuna* of origin of an outmigrant, but we have no way of pinpointing the *localidades* from which outmigrants originate. As such, this data cannot tell us if migrants are rural or urban. This is problematic because forest plantations are largely a rural phenomenon and thus, we must measure rural out-migration. Consequently, analyses considering the relationship between forest plantation expansion and out-migration must isolate rural localities. Since the census does not provide this level of data, we instead measure population decline. We use population decline as a reasonable proxy for out-migration drawing on two other recently published studies addressing similar questions that also use population decline as

a proxy for out-migration [11,13]. We use our qualitative data to both explain and strengthen the quantitative findings, in light of these limitations in the data.

We created a panel dataset of rural communities in La Araucanía between 1992 and 2017, a period that witnessed a great expansion of the forestry industry in southern Chile [11]. The dataset includes socioeconomic and demographic information as well as information regarding the expansion of the forestry industry in each *comuna* where the rural communities are located. We used the definition of a rural community provided by the Chilean National Institute of Statistics (INE), which is consistent in both the census of 1992 and 2017. We merged rural communities present in the census of 1992 with those in 2017. We were able to match 917 rural communities or *localidades* in both periods, which represents approximately 80% of the total rural communities in 1992. We could not match all the *localidades* because some of them do not exist in 2017, were divided, or merged with other *localidades*. We checked the unmatched cases and all of them are randomly distributed among the 32 *comunas* of La Araucanía. Finally, it is important to point out that the rural community or *localidad*, as unit of analysis, is the finest scale available in the census data.

We used two different sources to build the database. We obtained data on the area of land covered by forest plantations for 1997 and 2014 from CONAF, the Chilean National Forest Corporation. This dataset provides information about the area covered by forest plantations as a proportion of the overall area of each municipality. Second, we assembled data on rural communities from the census of 1992 and 2017. This dataset provides information on the gender, ethnicity, and age of all members of each rural community. To standardize these variables over time, we estimated the percentage of women, Indigenous residents, and age groups. Finally, we merged the forestry cover data with the rural community data. In other words, we have demographic variables for 917 rural communities in the early 1990s and late 2010s and the extents of forest plantations for each time period. This allows us to evaluate demographic changes and changes in forest plantation extents over time at the level of the rural community, the finest political division available.

To estimate the impact of the expansion of the forest plantations on rural population change in La Araucanía, we specified our difference-in-difference analysis using a longitudinal fixed effects regression model for each rural community and year. We used fixed effects models at the rural community level; this means we compared the same rural community over two periods of time and there are two supporting reasons for this. First, this strategy allows us to control for many potential confounders, even if they are not explicitly observed [28,29]. The rural community fixed effects regression controls for all omitted variables that do not change over time—for example, the geographical location, cultural background, norms, values, traditions, etc., and the year. Fixed effects models control for omitted variables that do change over time, provided the time trends are the same in different rural communities. Second, Andersson et al. compared random and fixed effects models using a similar dataset; they concluded that the specifications of fixed effects models are more suitable than those of random effects models [11].

Our model incorporates different control variables, which have been previously identified as relevant factors to explain out-migration. For example, communities with high levels of unemployment may create incentives for people to migrate [37]. Scholars have found that women and men follow different patterns of migration [44]. Education has been identified as a key variable to explain why people decide to migrate [37], and since the 90s the Chilean population has increased their education level [45]. Furthermore, La Araucanía is the area with the highest percentage of Indigenous people living in rural areas in the country and due to the occupation of the region by the Chilean state during the 19th and 20th centuries, the Indigenous population was forced to leave rural areas [46]. To control by different patterns of migration of Indigenous and non-indigenous population, we added the percentage of indigenous population living in each rural community in our model. Finally, previous studies have argued that the forestry industry could force the younger population to migrate due to the lack of job opportunities in the rural

areas [12]. To test this hypothesis, we divided the economically active population in six groups (dummy variables) in our model.

The fixed effects model can be specified as follows:

$$Y_{rt} = \alpha_r + \beta_t + \boldsymbol{\gamma FM}_{rt} + \boldsymbol{\gamma IN}_{rt} + \boldsymbol{\gamma HE}_{rt} + \boldsymbol{\gamma UN}_{rt} + \boldsymbol{\gamma AG}_{rt} + \boldsymbol{\gamma FP}_{rt} + e_{rt} \quad (1)$$

where α_r is a rural community fixed effect (a dummy for each community), β_t is a year fixed effect (a dummy for each year), and e_{rt} is an exogenous residual. To account for within-community serial correlation in e_{rt}, standard errors are clustered at the rural community level [47]. The dependent variable Y_{rt} represents the total population for a rural community r (we use a total of 917 rural communities in this study) in year t (we have information in years 1992 and 2017). In the case of the independent variables, the percentage of female population is represented by the vector $\boldsymbol{FM}_{rt}$, Indigenous people by $\boldsymbol{IN}_{rt}$, people with high school education by $\boldsymbol{HE}_{rt}$,, unemployment by $\boldsymbol{UN}_{rt}$, and individuals in each age groups (between 18 to 65 years) by $\boldsymbol{AG}_{rt}$. The key independent variable, the percentage of the municipality's area covered by forest plantation, is illustrated by $\boldsymbol{FP}_{rt}$.

2.4. Qualitative Methods

While the quantitative methods draw on 917 observations over all of La Araucanía, the qualitative methods necessarily take a different approach. We selected a rural zone located within the *comuna* of Victoria that includes the rural *localidad* of Selva Oscura, a village with a population of 1596, plus several smaller settlements spread throughout the countryside (Figure 1). For the purposes of this article, we refer to the qualitative study area—which includes the village and residents living in the surrounding countryside as "Selva Oscura" (see Figure 2). In Selva Oscura, like the rest of the La Araucanía, the forestry industry makes up an important part of land use alongside a productive system based on grains and raising cattle. We chose Selva Oscura to collect qualitative data because of the forest industry's recent entry at the end of the 1990s and early 2000s that corresponds with the fixed effects regression data (Figure 2), and because of the continued importance of smallholder agriculture and colonist small-scale agriculture in the region. Selecting Selva Oscura allows us to understand how livelihoods evolve alongside the relatively recent expansion of the forest plantations. We focused our study on *campesino* residents—residents who do not identify as Indigenous, in line with the larger goal of our study, which is to understand the impacts of the forestry industry on *campesinos* in particular, as land tenure and access in these communities are vastly different from the experience of Indigenous communities, and the large part of the research conducted on the impact of the forestry industries focuses on Indigenous communities [3,12,48]. We follow the mixed method approach outlined by Creswell and Creswell, who note that qualitative case studies are not meant to be widely generalizable, but are used to triangulate and confirm quantitative results, while adding richness and detail to knowledge of a given phenomenon [33].

The qualitative results presented in this article are based on 25 semi-structured in-depth interviews with rural residents from within Selva Oscura, as well as two participatory mapping workshops and one focus group conducted between 2019 and 2020. Interviews were conducted with men and women over the age of 18, usually in their homes and, due to the COVID-19 pandemic that interrupted in-person fieldwork in 2020, several were conducted over the telephone. The in-depth interviews addressed themes related to individual and family experiences of forestry expansion, land use change, and migration experiences, among other topics of importance to the participant. Mapping workshops were conducted with one group of 10 older adults and a group of 15 adult women and men to understand land cover, land use, and land tenure change and the meanings of these changes in participants' lives over the years and their possible effects on migration. Participatory techniques help to access local knowledge surrounding research questions, and use accessible techniques, such as drawing, diagramming, and brainstorming, to overcome power disparities between researchers and research "subjects," in an effort to

produce data from the bottom-up [49]. Participatory workshops were facilitated by the authors of the study and centered on small group activities during which participants worked together to interpret landcover maps of the Selva Oscura case study region from the 1980s to 2017. Land uses, landcover, and land tenure were traced onto overlays by group participants. Eight residents, men and women, participated in a focus group on the perceived challenges and successes related to their rural lives and livelihoods today. Interviews, focus groups, and workshop participants were recruited using a purposive sampling technique through which researchers relied on local key informants to provide information on appropriate research participants meeting the following criteria: Participants must be adult residents of the study area. Additionally, we recruited participants with a range of life experiences—landless and small to medium-sized landholders, farmers and people who engaged in off-farm employment, as well as those with migrants in their immediate families or who had been outmigrants themselves. Interviews, workshops, and focus groups were recorded and transcribed. Qualitative data was coded for themes and concepts relevant to the research questions—for example, participants' experience of forest plantation expansion, land use and land cover change, data related to livelihoods and how they have changed over the years, and drivers of migration [50]. Once coding was completed, codes were then sorted and compared, and conclusions were drawn. Data was triangulated among sources to ensure validity of results. The study has Institutional Review Board approval and all names have been replaced by pseudonyms.

3. Results: Population Loss and Forest Plantation Expansion in La Araucanía

3.1. Fixed Effects Regression

Descriptive statistics of the variables are presented in Table 1. The table shows the mean, minimum, and maximum value of each variable from the Census in 1992 and 2017 (row a), and 1997 and 2014 for information about area covered by forest plantation (row b). Furthermore, the column VIF (Variance Inflator Factor) indicates that there is no multicollinearity among the independent variables utilized in the model.

Table 1. Descriptive statistics for analysis variables.

(a) Census of Population	**Obs**	**1992**			**2017**			**Variance Inflator Factor (VIF) ***
		Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	
Total population (dependent variable)	917	253	1	2102	213	2	3065	
Demographic and socioeconomic variables								
% of female population	917	45	0	70	47	0	70	1.17
% of Indigenous population	917	25	0	100	50	0	100	1.12
% adult population with high school educ	917	16	0	100	31	0	75	1.34
% adult pop unemployed at the rural community level	917	3	0	21	3	0	39	1.11
% adult pop unemployed at the municipality level	917	3	1	5	4	2	5	1.26
Economically active population								
% population between 18–20 years	917	5	0	50	3	0	19	1.24
% population between 21–25 years	917	9	0	50	5	0	23	1.31
% population between 26–30 years	917	8	0	50	5	0	25	1.29
% population between 31–40 years	917	13	0	38	11	0	38	1.28
% population between 41–50 years	917	10	0	100	14	0	50	1.45
% population between 51–65 years	917	12	0	63	22	0	67	1.83
(b) Chile's Forestry Service (CONAF)		1997					2014	
% area covered by forest plantation	917	15	0	41	25	0	61	1.09

* Small VIF values indicate low correlation among the independent variables; ideally, VIF should be below 5 [51].

Table 1 shows that rural communities' population has decreased over time. In 1992, the number of inhabitants, on average, per rural community was 253 people. In 2017, the average population decreased to 213 people. In 1997, approximately 350,000 hectares were covered with forest plantations, and the number increased to around 630,000 in 2014,

which represents 20 percent of the overall territory of La Araucanía. Figure 2 shows that Selva Oscura, where the qualitative sampling was performed, experienced an important growth of forestry industry in the same period.

Can the expansion of the forestry industry explain the decline of rural communities' population? To answer this question, we ran a fixed effects regression model in which the dependent variable is the total population of rural communities in La Araucanía. The key independent variable is the percentage of area of each municipality, where the rural communities are located, covered by forest plantation. Different factors can influence people's decision to leave their rural community, variables such as unemployment, age, gender, ethnicity, or education can be key to explain population decline in rural areas. We used these variables as covariates in our model. In this way, we control for factors, different than the expansion of forestry industry, that also can explain the migration of people from rural areas in region.

Table 2 shows the outputs of three regression models with different control variables. The first model uses only our main independent variable, the percent of the municipality's area covered by forest plantation, and it shows that as forest plantations cover larger extents of land, the rural population declines. In fact, one percentage of increase of the municipality's area covered by forest plantation implies the decrease, on average, of 1.95 persons in rural communities, and this coefficient is statistically significant ($p < 0.05$). The second model adds variables such as the percentage of female population, Indigenous population, adult population with high school education, as well as unemployment rate at the community and municipality levels. The outputs show that after we control by demographics and socioeconomic variables that can influence the decline of rural population in La Araucanía, the coefficient for the expansion of forestry industry is still negative and statistically significant. In other words, the second model shows that the expansion of the forestry industry is linked with the decline of rural population in the study area. Finally, the third model included the age of economically active population and the results are consistent with the previous models. That is, the expansion of forestry industry is associated with the reduction of rural population ($p < 0.05$) after we control by demographics and socioeconomics characteristics of the population. The output shows that 1% of the increase of the municipality's area covered by forest plantation implies a reduction, on average, of 1.83 persons of rural communities. Furthermore, it shows that those who stay in the rural communities are women, and those who leave are adults from 51 to 65 years. All coefficients are statistically significant ($p < 0.05$).

Table 2. Fixed effects regression model of the impact of expansion of forestry industry on the decline of rural population in the Araucanía region.

	Model 1	**Model 2**	**Model 3**
% area forest plantation	−1.95 *	−1.96 *	−1.83 *
Demographic and socioeconomic variables			
% of female population		1.39 **	1.21 **
% of Indigenous people		0.06	−0.23
% adult population with high school		0.51	0.09
% unemployment at the community level		1.11	0.88
% unemployment at the municipality level			2.63
Economically active population			
% pop between 18–20 years			0.78
% pop between 21–25 years			1.55 +
% pop between 26–30 years			1.53 +
% pop between 31–40 years			0.84
% pop between 41–50 years			−0.90
% pop between 51–65 years			−2.27 ***
Observations	1834	1834	1834

Number of rural communities	917	917	917

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

3.2. Case Study in Selva Oscura

The analysis of our qualitative data revealed three major themes related to population loss in the case study area. First, the expansion of the forestry industry in participants' communities led to a direct displacement of residents. Second, the forestry industry upset the availability of traditionally existing forms of employment, leading residents to seek elsewhere. And third, that the forestry industry caused difficulties in agriculture, incentivizing a withdrawal from rural livelihoods. We expand upon these themes below.

3.2.1. Displacement

In the most direct sense, the expansion of the forestry industry has led to out-migration through the displacement of certain rural residents. When the forestry companies purchase large estates, previous land uses, like agriculture or raising livestock, are replaced by non-native monocultures. Large estates are oftentimes home to not only the owners of the estate, but the estate's employees and their families, who have sometimes lived there for generations. Locally these workers and their families are called *inquilinos* and in some cases they live in clusters as large as small villages, some even having schoolhouses or chapels. *Inquilinos* do not own the land, but sometimes landowners provide a small parcel for them to farm for family subsistence. With the purchase of estates by the forestry industry, these families are automatically displaced from the farms where they reside. Matilde, a 36-year-old smallholder recalled how many of her friends moved away when she was a child and adolescent. She explained:

> *[…before there used to be a lot of people, lots of families. And they started to buy the estates and started, for example, like I told you, San Francisco was turned into a plantation, and all of that piece of land is just trees. So then, for example, they could have put more houses, more people there, but no.]*

3.2.2. Employment Opportunities

Interviews with community members suggest that the lack of access to full time, living-wage employment is one of the reasons that young people, in particular, must find work elsewhere. Participants were told that increasing forest plantations surrounding their villages and parcels would provide them with stable employment opportunities. However, many forestry industry jobs are temporary and mechanized, and depend on whether trees are being planted, fumigated, or harvested. While community members do find work on the forest plantations, employment levels are not what they expected. Macarena, a member of a smallholding family whose children have all left said: "we would say, 'people are going to have jobs, with respect to planting [the trees],' but no. All of that is done with machinery…" Community members link the arrival of the forest plantations to the lack of availability of off farm employment in the area. When the forestry industry purchased land and planted trees on neighboring large landholdings, or *fundos*, jobs that these large farms once offered disappeared. Zenia, a lifelong resident of Selva Oscura and long-time domestic employee on one of the neighboring *fundos,* explained her reaction when the forest plantations arrived in her village: "well, we worried that if things continued this way [forest plantations taking over *fundos*], people would lose work, just like what's happening now that there are so few *fundos* around us." Macarena echoed Zenia's observations: "whoever didn't have his own fields to work, worked on the *fundos* and they went selling off all of those *fundos* to the forestry companies, and they went finishing off everything [*y se fue terminando todo*]." She continued:

> *[Everything is pure forest plantation. The people are leaving because here there's no work, and so there are very few young people here…because they don't have any place to work, so instead of forest plantations, why didn't they do something else instead? I*

don't know, it could be blueberries, raspberries, strawberries, all of those things that they need people to work—more than anything for women.]

Macarena's reflection is common in the community—if the forest plantations were instead home to more labor-intensive berries—which are important commercial crops in the region—they might be better off. While Macarena indicated that with berries, more women could access employment through these arrangements, Lisa highlights other gendered aspects of unemployment in the area. Men, in particular, must leave to find work. When asked how the forestry industry expansion has impacted men and women, she explained: "there's a lot of women who are alone here." This is the case of Lisa, whose husband works outside of Selva Oscura, only coming back a few weekends a month. She expressed:

[…there are no jobs for the men…because now the minority of them work on the fundos, before it was the whole town, it was the majority. Well, before there was also less education and people had to work in the fields. Now it's more feasible to have a profession, and here they have to go away and work somewhere else.]

While participants agreed that the forestry industry has limited their access to jobs that were once available, they also recognize that the forces of modernity—for example, the mechanization of these farms in recent years or the greater access to education—have also led to a reduction of work opportunities and the desire to seek better-paying jobs in urban centers.

3.2.3. Forestry Industry and Agricultural Livelihoods

Besides the reduction of job opportunities, participants also attribute the growth of forest plantations in their communities to increased difficulties in small to medium scale agriculture, such as declining access to water resources. Community members blame these challenges, in part, for the decline in the younger generation's desire to continue in agricultural livelihoods. In this context, forest plantation expansion is one of several problems that participants view as unfavorable outcomes for smallholders.

Participants mentioned a host of environmental impacts stemming from afforestation with exotic species, including decreased water availability, increased shade, dust, and pollen covering vegetation, and drift from chemical applications in the plantations. Monoculture forest plantations were linked to declining water resources and a lowering of the water table, which could cause a drying of soils, wells, and irrigation canals. For example, many participants across the study region rely on water delivery by the municipality during summer months because their wells are dry. While La Araucanía has experienced a drought in research years, research has shown the negative impact of plantations on water resources. Despite the drought, community members placed clear blame for their water access problems on the surrounding plantations. A medium-sized family producer described the impact on his crops in a focus group:

[The eucalyptus, for example, that are planted alongside the fields of all of our neighbors, man, the water dries up quickly because the roots are extremely long, so it really affects the water consumption… they say, 'no, your field is next door,' but actually the roots are in the middle of the neighboring field!]

Community members noted that when trees are harvested, they observed that the water returns. For example, Macarena explained that on her parcel, "*there used to be a stream and now there's only a little thread of water, and it's all because of the forest plantations. My husband says that when they cut it down we're going to see that we'll have water again...*"

Participants agreed on several other problems, also mentioned in interviews. For example, the problem of shade produced by larger trees. Shade blocks the sunlight, which is necessary for healthy crop development. A smallholder who grows wheat or oats depending on the year explained, "*I have a very narrow parcel, and about 50 m of it borders a forest plantation. So, the trees are about 40 m high, and so the shade [from these trees] really affects this… What I plant doesn't grow as much as it should*." Others told us that the "pollen" or

"dust" falls from the trees onto their fields, impeding crop growth. This occurs because the forest plantations are planted too close to their fields, according to the participants, "*They plant the trees very close to the fences, they don't leave a big space, so then the branches and everything, they expand next to one's field*." Another added, "*and after all, these are small fields, of course." Another issue affecting production, according to residents, is chemical drift from fumigation of plantations by airplanes. For example, one participant indicated, that, "yes [our farm] produces, but you always have to stay on top of the forest plantation because when they "fumigate" it touches part of your crops, and it burns part of them*."

These challenges have made pursuing agricultural livelihoods more difficult in a context that is already unfavorable for small to medium scale farmers. "*The kids, almost all of them leave,*" Juan, a smallholder, told us one afternoon. "*It's just us little old men working in the fields. The young people don't like working on the farm, they make too little money," he laughed, and "there's a bad internet signal*." This is a pattern that residents of Selva Oscura frequently mentioned. Young people are not attracted to agricultural life; they do not like it because, as Juan suggests, of the few returns this livelihood provides. Many years ago, there was a large "*quantity of people, there were so many people in this sector. Now the only ones left are old people, young people don't want to work in the fields…Everyone is thinking about going to the city, in the end, at least our kids. Our generation no. There's little chance that anyone would follow us*." Another medium-sized producer, Samuel, added, "*The kids, the first thing they're going to do [when we die] is sell, we're battling to be able to subsist here, and they're thinking about us dying so they can sell right after. The subdivisions affect us—the land sizes are becoming smaller and smaller, when they're subdivided, the plots that remain are even less profitable because they're very small lands. So then, they have to migrate*." While the migration experiences related by Juan and Samuel are not directly connected to forestry plantation activities, they highlight a context in which agricultural livelihoods are challenging to pursue due to decreased land access and the decreased returns of small to medium-sized agriculture. It is within this context in which forestry plantation activities disrupt farmers 'already precarious livelihoods.

4. Discussion and Conclusions

Recent research has set out to evaluate the socioeconomic impacts of the expansion of the forestry industry in southern Chile. While the industry's boosters argue that forest plantations benefit local communities by providing employment opportunities, investing in infrastructure and community-based initiatives, for example, a growing number of studies highlight the negative externalities of the expansion including rising poverty and inequality, as well as water scarcity. They also find that the expansion of the forestry industry is not associated with lower levels of unemployment and an increase of pay or household incomes. Another claim is that the forestry industry has led to an abandonment of the countryside. However, existing research does not address the question of population change or migration associated with the expansion of exotic forest plantations directly nor does it elaborate upon the processes that lead to migration or illustrate the context in which migration unfolds. This article contributes to this literature by addressing the following questions: Is there a relationship between forest plantation cover change and out-migration from rural areas? If so, what are the factors that explain this process? Our findings advance understandings of the linkages between extractivist, non-native forest plantations and out-migration. The mixed methods approach we used combines robust statistical tests to establish a relationship between the two phenomena, uses important time periods, and engages with migration studies, which leads to a more nuanced interpretation of the linkages.

The results of our fixed effects regression model indicate a statistically significant relationship between population loss and greater extent of monoculture forest plantations in La Araucanía. As plantation cover expanded from 350,000 ha to 630,000 ha between 1997 and 2014, rural communities in municipalities experiencing the brunt of this increase lost population. The negative relationship holds true even when we controlled for other

possible causes of rural population decline, such as education levels and the unemployment rate. Importantly, our results dispute the assumption that an increase in forest plantations would help to keep the rural population stable over time, by providing increased employment opportunities to rural residents.

The quantitative results differ from findings offered by Andersson and colleagues' [11], who do not find a significant link between population decline in areas with greater extensions of forest plantations. The authors used the size of rural population aggregated at the *comuna* level during the period from 2000–2011, but this could be problematic because the change of population, most likely, is occurring at a finer scale, and using aggregated data could obscure relevant information for estimating the impact of the forestry industry on population decline. Furthermore, the study only used one control variable: urbanization. Our research takes into account these limitations in three ways. First, we study population change at a finer scale; our unit of analysis are 917 *localidades* (rural communities). Second, we use different demographic, educational and economic variables as confounders in our fixed effects regression model. And finally, our dataset has a longer temporal extent. Nevertheless, our results echo those found in another recent study from the neighboring Bío Bío Region, which has a longer trajectory of forest plantation intervention than La Aruacanía, and the Ñuble Region. Cerda and colleagues [13] find that an expansion of plantation cover correlates to population decline, which they attribute to out-migration due to the increase in poverty that also corresponds to this change in land use.

The qualitative case study supports the hypothesis that population loss is related to out-migration. Participants conveyed the widespread belief that forest plantation expansion can be associated with rural residents leaving. However, our results reveal that this relationship is more complex than what previous studies have proposed. Others have directly linked migration with higher poverty levels [11,13]. However, by applying our approach, informed by recent literature calling for a political ecology of migration and examining the phenomena from the perspective of migration studies, we reveal how migration is a multifaceted process linked to rural change, with forest plantation expansion unleashing several underlying issues that are potential drivers of migration. These include increasing difficulties for small and medium scale agricultural production and the loss of previously available employment opportunities on neighboring farms, in addition to direct displacement of families. This could be for two reasons: First, because forest plantations do not employ many people, and if they do, it is often on a temporary basis and many are mechanized thus reducing the overall number of jobs. Second, their workers may come from outside the community or *comuna*. These conclusions reflect similar findings on extractivism from other places in Latin America. In Guatemala, for example, the expansion of extractivist agrarian production of sugar cane, African palm, and other products has also been associated with poor labor market outcomes, like loss of job opportunities and the compression of wages [30,52]. An initial phase of out-migration was caused by direct displacement of *inquilinos*, farm workers and their families who lived on large estates, often for generations. When large estates were sold off to forestry corporations, *inquilinos* were forced to migrate. We find that on the one hand, migration is part of processes common to de-ruralization—the subdivision of lands, decline in dependence on small-holder farming livelihoods, and rise in education rates. On the other hand, migration is linked to processes rooted in the expansion of forest plantations in the area, namely because rural job opportunities have diminished and a sense of difficulty in agriculture and agricultural opportunities for farmers and their families.

With the qualitative case study, we add complexity to the results of our quantitative results: While extractivist, non-native forest plantation expansion is related to population decline, we find that plantation expansion itself is a trigger for a number of other associated changes that encourage people to abandon the countryside. Thus, the qualitative data illustrate that migration can be linked to trends common to rural transformation, such as changing rural livelihoods, but that the introduction of forest plantations to the region in

the late 1990s is viewed as one of the factors leading to these changes and perceived as a push factor by participants in our study.

Our results contribute to knowledge of the impacts of the forestry industry on rural spaces across the region. Activists, residents, and scholars alike have long sounded alarms about the harm they have experienced in their communities from forestry expansion. Much of the empirical work to date on these impacts have focused on Indigenous communities, which have borne the brunt of the negative externalities of forestry expansion. Our findings demonstrate the broader impact this expansion has had on rural spaces in general. In particular, the qualitative findings highlight the hardship that the forestry industry has implied for landless and small to medium sized non-Indigenous farmers who have been displaced from the land or have had increasing difficulties, including declining water access, in continuing with agriculture due the existence of more forest plantations around their parcels.

There are several limitations to our study that we should state. First, the dataset used only considered two time periods—the late 1990s and 2014—for the expansion of the forestry industry in La Araucanía. We did not incorporate data from the early 1990s, when the forestry industry started expanding in the Araucanía Region, because data are unavailable for this time period. Future studies could overcome this limitation by using remotely sensed data from the early 1990s. Second, while the results indicate a negative relationship between population decline and forestry industry growth, we are cautious about the assumption that population loss is related to out-migration. Internal migration data is not available to answer our research question. We acknowledge that using population loss as a stand-in for migration is imperfect because population loss may also be caused by an increase in mortality rates or decrease in fertility rates. We base our use of this proxy on two previous studies, which explore a similar question, albeit using different approaches. Nevertheless, our study shows that the expansion of the forestry industry has impacted population in rural communities. It does not prove a causal relationship; in this sense, the results need to be interpreted carefully. Third, while we control for several possible confounding factors, there is the possibility that unobserved factors could explain out-migration. For instance, in our study, we do not consider variables such as poverty, fertility, or mortality rate that, according to the literature, are linked with population decline, because this information is not available at the rural community level. However, we are confident that our results are consistent because poverty has decreased in La Araucanía from 46% in 1990 and 17% in 2017 [40]. Furthermore, and even though the fertility rate has decreased in Chile since the 90s, life expectancy has increased, and therefore, the effect of both variables is canceled out. Finally, another possible limitation is related to the nature of our mixed methods approach. Although our quantitative study is representative of rural areas across La Araucanía, our explanatory qualitative case study, due to its limited geographical scope, may be less representative of the area. However, because of the similarities between Selva Oscura and other *localidades* in the region, our key findings do help to explain processes of outmigration being experienced in other rural zones throughout the region.

Our exploration of questions related to migration and monoculture, exotic forest cover expansion in southern Chile contributes to both academic and policy-related debates. On the one hand, because of our migration studies approach, we demonstrate how land cover change, driven by extractivism, is linked to out-migration in rural areas providing further evidence to a growing body of research in the field of political ecology of migration that seeks to critically examine both the political-economic and environmental drivers and consequences of migration. On the other hand, this article contributes evidence to support informed decision-making regarding the forestry industry in southern Chile at an urgent moment. In light of widely supported protests beginning in October 2019 and the 25 October 2020 referendum decision to re-write Chile's Pinochet-era consti-

tution, the nation is taking into account the neoliberal legacies of its former military regime. The forestry industry is an important part of this legacy and Chileans will likely have voice in shaping how this type of development unfolds in the future.

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