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Time Series Analysis of Forest Stewardship Council (FSC) Certified Area in Latin America 2013-2025

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Abstract

The FSC is a forest certification system which develops sustainability standards for forest management. Present in over 80 countries FSC continuously seek in its strategic planning to increase certified area worldwide, however, even with a huge forest aptitude, Latin America has notably few areas certified by this important tool for responsible forest management as compared to Europe or North America. In this study, by carrying out a time series analysis of FSC-certified areas in Latin America between February 2013 and April 2025, we sought to evaluate the characteristics of this series, identify points for intervention and adjust predictive models. We used FSC-certified area data publicly available on the FSC international website and processed the time series using Gretl software. The results demonstrated a growth trend in the FSC-certified area in Latin America; and the intervention analysis revealed significant dates that may change the time series behaviour. Two models were fitted, with and without intervention, of which the model without intervention presented the lowest MAPE, making it the best candidate for predicting the FSC-certified area in Latin America. Time series analysis proved to be a powerful tool for identifying dates to be further explored within the FSC system, deepening understanding on events that potentially influence the increase or decrease in the certified area. Future work may correlate other time series that could also characterize and indicate key points to understand FSC system and pursuit of expansion of sustainable forest management in Latin America.

Keywords: *Temporal Analysis, Forest Certification, Latin America, Chemical Wood Pulp Forest Market.*

1. Introduction

While forest preservation is becoming increasingly essential in confronting the global climate crisis, it is unlikely that humans will be able to forgo the extraction of forest resources, primarily timber, but also non-timber products such as fruits, nuts, pharmaceuticals, etc. This poses a major challenge to forest product consumers (both forest managers and society in general) namely, the sustainable use of resources in order to ensure the integrity of ecosystems, aiming to enable the perpetuation of forest resource use and the ecosystem services they provide. This is no easy task, given that the rate of net forest loss between 2010 and 2020 was 4.7 million hectares per year, and a net area of 178 million hectares has been deforested since 1990 (FAO, 2020).

According to MacDicken *et al.* (2015), the promise of forest resource sustainability is rooted in two premises: first, that ecosystems have the potential to renew themselves; and second, that economic activities and social perceptions or values that define human interaction with the environment are choices that can be modified to ensure the productivity and health of ecosystems in the long term. The central challenge of managing the forest's regenerative capacity so as to produce benefits in the present without compromising future benefits and choices is at the heart of most visions of sustainable forest management. Based on this precept, two points must be addressed: the use of sustainable forest management practices to ensure the environmental and sociocultural integrity of the landscape; and, the demonstration to consumers that forest-based products available on the market were produced through environmentally sound, socially just, and economically viable practices, in order to encourage choices geared toward more sustainable consumption.

In this context, the Forest Stewardship Council (FSC) was created in 1993 with the goal of promoting sustainable forest management and establishing a market presence by identifying responsibly managed forest products through a forest certification seal. The FSC is considered the most relevant forest certification system worldwide, developing standards, policies, guidelines, and directives aimed at promoting good forest management practices (Azcárate *et al*., 2020). The FSC standards demonstrate by its 10 principles, an approach to reducing environmental and social impacts through assessments on: the effects of operations on the territory; biodiversity monitoring; care for workers, indigenous peoples, and surrounding communities; among others (FSC, 2023). The FSC is a valuable tool worth studying in order to better understand challenges, opportunities and to ensure its widespread use (Rametsteiner & Simula, 2003; Pattberg, 2005; Santiago *et al*., 2013; Rana & Sills, 2024).

The FSC is currently present in more than 80 countries, certifying approximately 167 million hectares of forest area globally (FSC, 2025). Despite its weighty contributions to sustainable forest management, only about 4% of the global forest area estimated at 4.06 billion hectares by the FAO (2020), is FSC-certified, which indicates enormous growth potential for this forest certification system. The largest proportion of FSC-certified areas is in Europe, with 64 million hectares, followed by North America, with 59 million hectares, and Latin America, with approximately 19 million hectares (FSC, 2025). The difference in certified area between North America and Europe is noticeably small as compared to the dramatically larger gap when Latin America is considered. Brazil, which is the largest forest holder in Latin America, with approximately 497 million hectares, has approximately 9 million hectares certified by the FSC, representing only 1.8% of the country's total forest area. However, Brazil is the country with the greatest loss of tree cover in the world, with an estimated average reduction of 1.4 million hectares/year (FAO, 2020), calling urgent attention for the implementation of sustainable forest management tools.

In this regard, the FSC Global Strategy 2021-2026, established the goal to certify 300 million hectares by 2026, of which 50 million hectares are from natural tropical forests and areas managed by smallholders (FSC, 2020). Therefore, it is worth evaluating the historical and current trends of FSC forest management certification, as such work develops understanding of factors that affect the scope of the FSC-certified area and implementation in different global regions (Azcárate *et al*, 2020). Given the large difference in scope of FSC area in Latin America as compared to North America and Europe, as well as the urgent need to apply tools that provide the means for ecosystem preservation and sustainable forest management in this region, a temporal evaluation of the Latin American FSC certified area time series is fitting — in order to obtain results that support debates and deepen understanding of the political, economic, environmental and social factors of their times (Basso *et al*., 2018; Azcárate *et al*., 2020; Corticeiro *et al*., 2025) and also specifically by region or country (Tricallotis *et al*., 2018; Tahvanainen *et al*., 2024).

Studying time series models may be of great interest to predict production, export and export behaviour, consumption and even a possible lack of forest products in global market scenarios, providing subsidies for decision-makers (Upadhyay *et al*., 2025). Through this study we sought to expand knowledge and identify specific years and dates of influence on the FSC-certified area through time series analysis (Morettin & Toloi, 2006), focusing on Latin America in order to identify points of intervention that may have impacted the presence of the FSC in this region between February 2013 and April 2025. Furthermore, we aimed to characterize and evaluate the time series used here and fitted mathematical models that serve to estimate the certified area in Latin America in the future, presenting a tool to better estimate the contribution of this region´s certified area towards FSC global strategy. Next, we present the methodology, followed by the results, discussions, and conclusions.

2. Methodology

The time series used in this study corresponds to the FSC-certified area in Latin America, measured in hectares (ha), obtained from the FSC International official website (https://connect.fsc.org/impact/facts-figures). The FSC publishes certified area data, disaggregated by region, including Latin America. The publicly available dataset includes certified area values annually from January 1993 to December 2012, and from February 2013, onwards, the FSC certified area is available monthly. For the purposes of this study, we used the monthly values covering the period from February 2013 to October 2025.

Since one of the objectives of this study was to generate mathematical models for future forecasting, the last six records in the dataset (May-25 to Oct-25) were withheld to allow for comparison between real data and the values generated by the models. Therefore, all the analyses were made considering the monthly time series from February 2013 to April 2025. To generate forecast models, as well as intervention analyses, we followed the methodology presented by Morettin & Toloi (2006). Data processing was conducted with GRETL software (2021). Model performance was compared by calculating the MAPE (Mean Absolute Percentage Error), according to the following formula:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{|Ai - Fi|}{|Ai|} \times 100\right)$$

Where:

- n is the total number of samples;
- Ai is the real value for sample i;

• Fi is the predicted value for sample i.

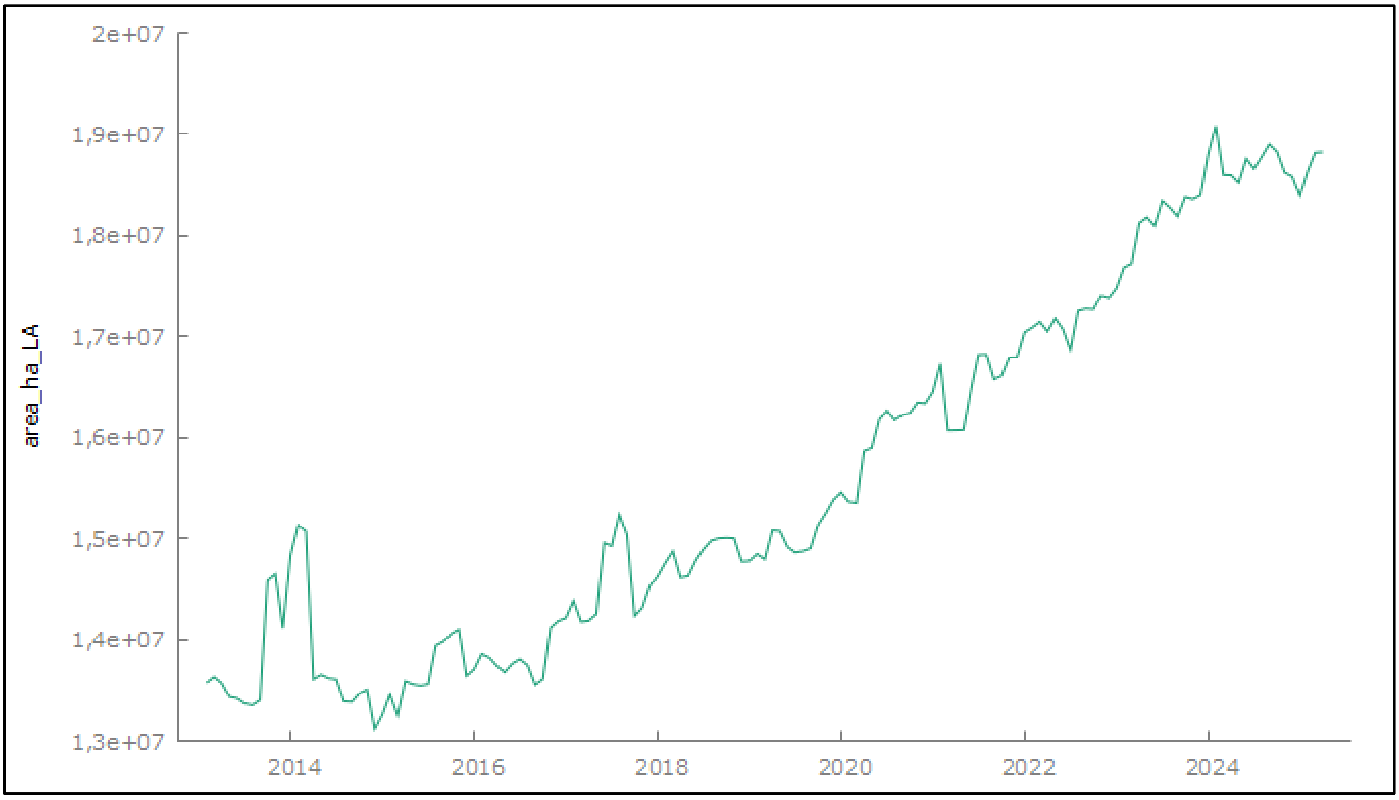
3. Results and Discussion

Forest management certification has played an increasingly important role in global forest governance over the past two decades, with the certification scheme developed by the Forest Stewardship Council since 1993 being undoubtedly the most significant in tropical regions in terms of area coverage (Azcárate *et al*., 2020). FSC functions both as a management tool for continuous improvement as well as a market instrument, and it may be influenced by internal factors within countries or even global economic dynamics. The challenges involved in obtaining FSC forest certification include complex documentation requirements, high costs, and the need for ongoing compliance audits, prompting researchers to explore and better understand the specificities of this certification system (Rafael, *et al*., 2018; Halalisan *et al*., 2023). By investigating the unique aspects of the FSC certification system, some researchers aim to identify barriers and solutions that can help expand its adoption and encourage more widespread responsible forest management.

Basso *et al.* (2018) conducted documentary research on FSC certification in the Americas in order to understand external factors that may influence FSC forest certification processes on this continent, looking at the increase or decrease in certified area. According to the authors, the most frequently reported influence identified through the analyzed documents was international market demand; that is, forestry organizations seek certification as a way to ensure compliance with social and environmental requirements imposed by international markets. However, this study, by combining countries from the Northern and Southern Hemispheres in a single joint analysis, lack to explore the significance of reported events in the increase or decrease in FSC certified area for these regions, which present very different forest and economic characteristics, due to their climate region and geopolitical context.

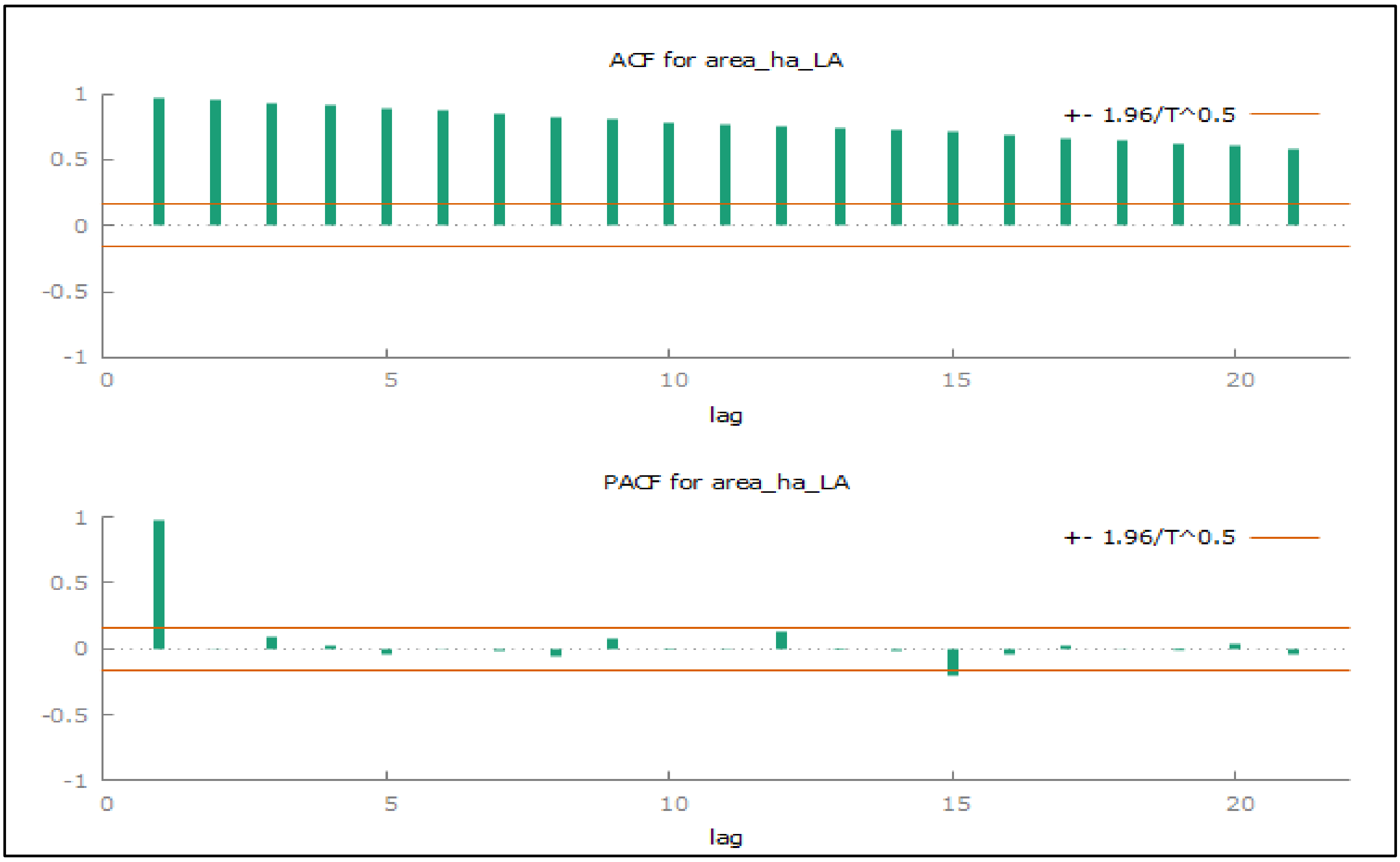
According to Azcárate *et al.* (2020), who evaluated FSC forest certification in the tropics through the analysis of public audit reports between 1995 and 2016, the certified area in this region has experienced a period of stagnation, particularly since 2009, unlike the global certified area, which has grown considerably during this same period. This reflects current FSC certification data globally, indicating that the vast majority of growth in FSC-certified area from 2009 to 2016 occurred outside the tropics, and raising concerns about the state of forest management certification in countries with tropical forest cover. These observations were the main driving factors for our choice of time series used in this study. The plot of the Latin America certified area time series from February 2013 to April 2025 (Figure 1) demonstrates an increasing trend in general, with a continuous growth trend over time. Visually, peaks of sudden increase followed by sharp decreases are also observed, which may characterize intervention points - that is, situations that occurred and affected or are still affecting the behaviour of the time series (Morettin & Toloi, 2006).

Figure 1 - Graph on the FSC Latin American certified area between 02/2013 and 04/2025.



The growth trend behaviour can be seen in the correlogram of the series, which shows several autocorrelation values outside the confidence interval calculated on the Autoregressive (AR) part of the autocorrelation graph, characterizing a nonstationary time series (Figure 02).

Figure 2 - Autocorrelation function and partial autocorrelation of the original series.



After identifying the increasing trend in the series, we calculate the squared time trend to fit the forecasting models and carry out the intervention analysis, as follows.

3.1. Forecasting Model

Model fitting using time series is based on the premise of obtaining models with the smallest number of parameters, that is, simpler models are preferable (Morettin & Toloi, 2006). The first model fit, referred to here as model I, was: AR (1), presenting all significant coefficients: const = 1.36436e+07; phi_1 = 0.755658; e sq_time = 265.861 (Table 1).

• Model I:

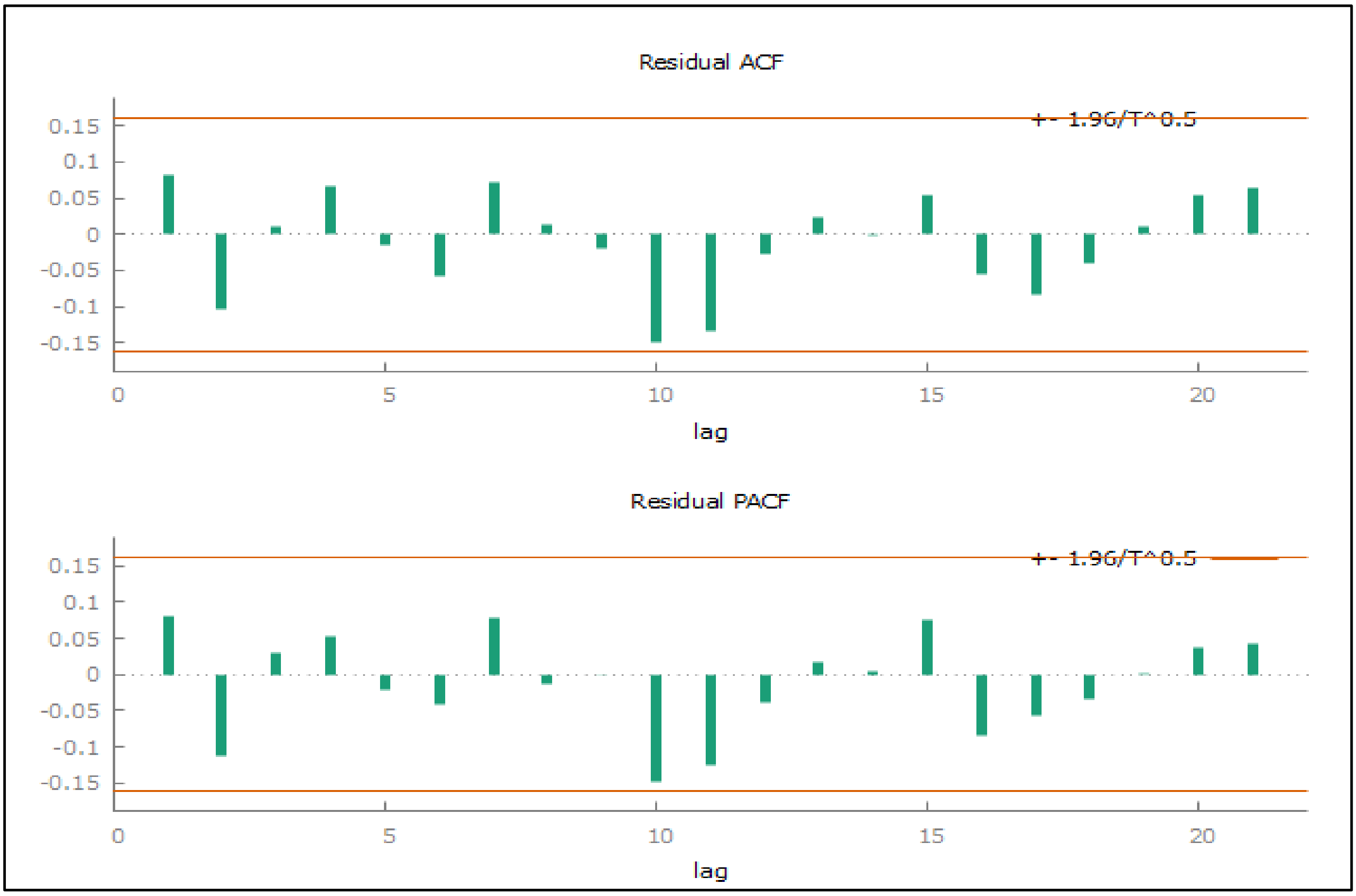
$$y_t = 1.36 \times 10^7 + 256.86\, t^2 + 0.75\, y_{t-1} + e_t$$

Table 1 - Results of Model I Fit AR (1) and coefficients.

Parameters	coefficient	std. Error	z	p-value	Significance
const	1.36436 e+07	119860	113.8	0.0000	***
phi_1	0.755658	0.0541587	13.95	3.03 e-044	***
sq_time	265.861	119.751	22.20	3.34 e-109	***

The correlogram of the model I residuals presented all autocorrelation values within the confidence interval (Figure 3), with the last autocorrelation value presenting a p-value of 0.763, i.e., > 0.05, characterizing the residuals as white noise, which demonstrates a good fit of the AR (1) model for this series.

Figure 3 - Correlogram of Model I residuals.



After verifying that the residuals behaved as white noise for the adjusted model I, it was possible to proceed with the intervention analysis.

3.2. Intervention Analysis

The plot of the original series (Figure 1) shows some variations to be larger than others throughout the series, possibly due to an event that affected the data behaviour. In which case, the impact of such an event on the series and its significance can be analyzed. By applying the analysis of effective values, adjusted values, and residuals, significant values were identified for five dates: October 2013; January 2014, April 2014; June 2017; and October 2017. One date in 2013, two dates in 2014 and two others in 2017. In these specific years and months, there may have been relevant gain or loss of certified area that affected the series. Azcárate et al. (2020), who studied factors that influence forest certification in the tropics over a 20-year period, explained that a myriad of factors can influence the likelihood of a forest management unit maintaining its certification over time, and reported a wave of certificate terminations in 2008, which could be considered an intervention — that is, an event that influenced the time series of total certified area in countries located in the tropics.

To fit the intervention model, two dummy variables were added contemplating the significant dates, one for the period from October 2013 to April 2014 and another one from June 2017 to October 2017, creating specifics regressors variables seeking better adjustment of model I. Next, the model was fitted again including the dummies. Model II: ARX (1), presenting all significant coefficients, const = 1.35407e+07; phi_1 = 0.654521; sq_time = 274.184; Dum_oct_13_apr_14 = 736882; e Dum_jun_17_oct_17 = 375105 (Table 2).

• Model II:

$$y_t = 1.35 \times 10^7 + 274.184\, t^2 + 0.65\, y_{t-1} + 736882\, x_t + 375105\, z_t + e_t$$

Where the dummy variables assume:

$$xt = \begin{cases} 1, if\ t\ \varepsilon\ (10/2013 \text{ a } 04/2014); \\ 0, cc \end{cases}$$

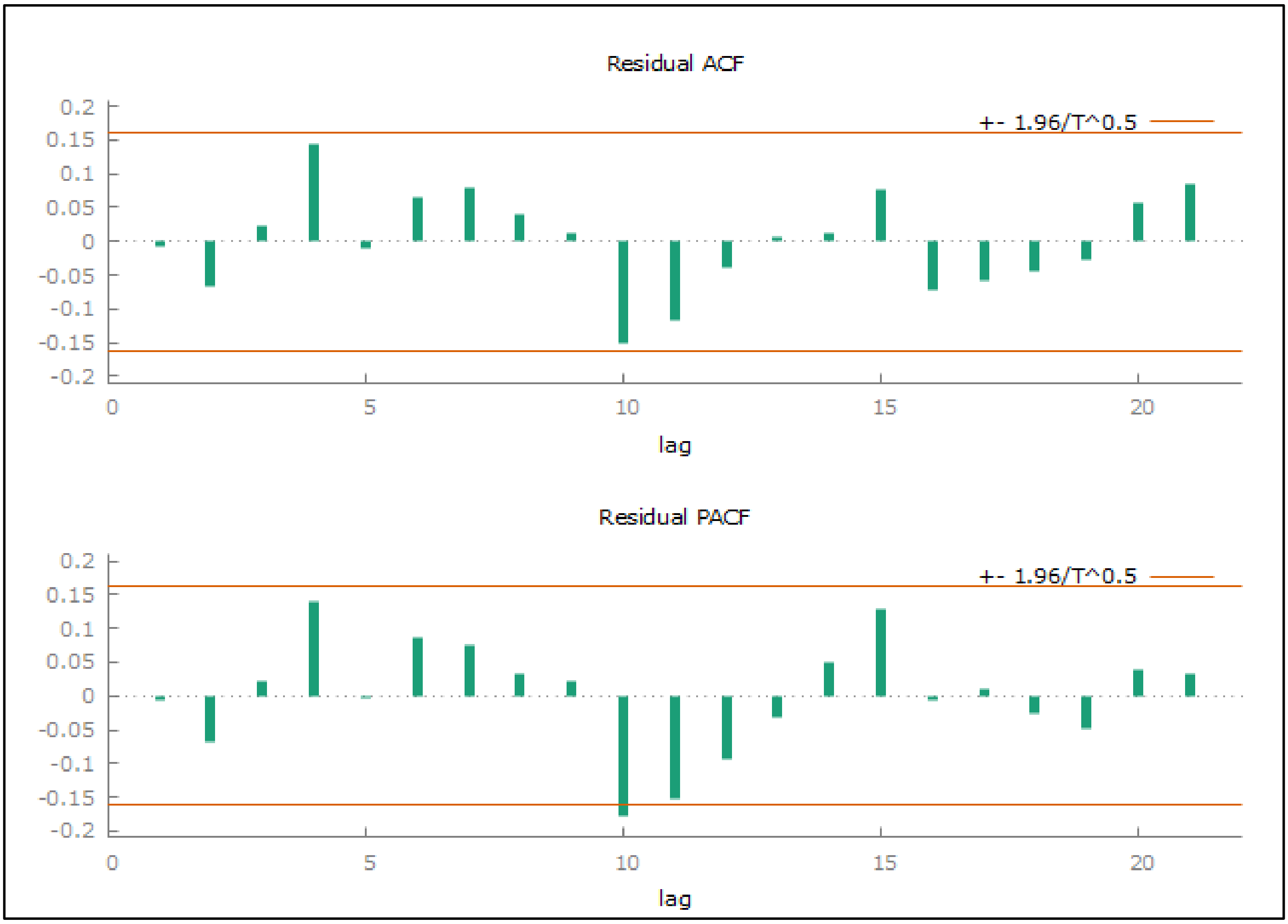
$$zt = \begin{cases} 1, if\ t\ \varepsilon\ (06/2017 \text{ a } 10/2017); \\ 0, cc \end{cases}$$

Table 2 - Model II Results and coefficients ARX (1).

Parameters	coefficient	std. Error	z	p-value	Significance
const	1.35407 e+07	83022.5	163.1	0.0000	***
phi_1	0.654521	0.0675462	9.690	3.33 e-022	***
sq_time	274.184	8.28377	33.10	3.07 e-240	***
Dum_oct_13_apr_14	736882	167473	4.400	1.08 e-05	***
Dum_jun_17_oct_17	375105	167905	2.234	0.0255	**

It is also possible to notice from the signs of the dummy variables "Xt" and "Zt" that the intervention's contribution was positive, that means that in these time periods there were a more pronounced increasing behaviour on the series. The Correlogram of model II residuals showed most of autocorrelation values within the calculated confidence interval (Figure 4), with the last autocorrelation value presenting a p-value of 0.670, that is, > 0.05, thus characterizing the residuals as white noise. This demonstrates a good fit of the ARX (1) model.

Figure 4 - Correlogram of Model II residuals.



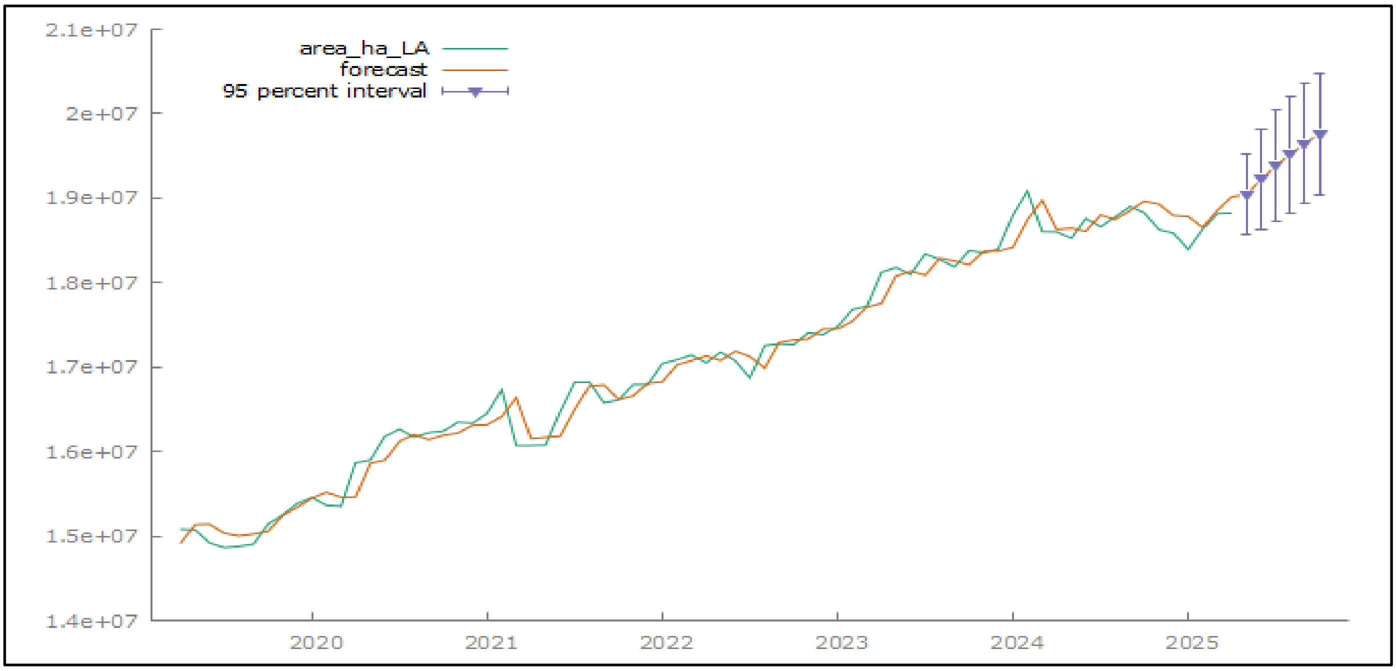
Once the model fit with and without intervention were complete, we compared the two in order to determine which would be the best candidate for estimating the FSC certified area in the future.

3.3. Model Comparison

Two models were fitted, model I without intervention (Figure 5) and model II with intervention (Figure 6), which were compared below based on the actual values from the last 6 months, which had been initially withheld from the series.

• Forecast Model I:

Figure 5 - Forecast plot and values for the next six months Model I. For 95% confidence intervals, z (0,025) = 1,96.



• <u>Forecast Model II</u>:

Figure 6 - Forecast plot and values for the next six months Model II. For 95% confidence intervals, z (0,025) = 1,96.

Using the forecast values for both models, we calculated the MAPE (Mean Absolute Percentage Error), which yielded the following results (Table 3):

Table 3 - Comparison between models - MAPE calculations.

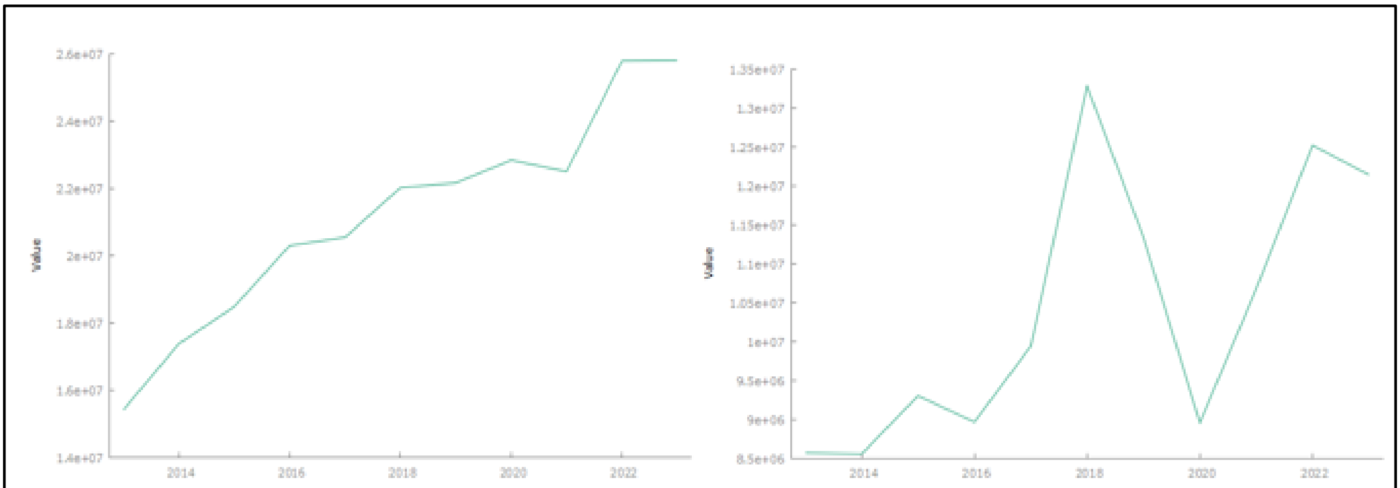
Original data series			Model I		Model II (w/ intervention)	
Year	**Month**	**Value**	**Prediction**	**|Difference/real value|**	**Prediction**	**|Difference/real value|**
2025	5	18966961	19040165	0,00386	19126341	0,00840
	6	19003810	19223435	0,01156	19352920	0,01837
	7	18936621	19381750	0,02351	19529901	0,03133
	8	18900690	19521336	0,03284	19674611	0,04095
	9	18778759	19646901	0,04623	19798387	0,05430
	10	19012568	19762000	0,03942	19908651	0,04713
			Total	**0,15741**	**Total**	**0,20048**
			MAPE (%)	**2,6235**	**MAPE (%)**	**3,3413**

Based on the MAPE results, it is worth highlighting the low percentage values obtained and the tiny difference between them, indicating an excellent model fit: Model I = 2,62% and Model II = 3,34%. When comparing the models' forecast MAPEs, we observed that model I (without the intervention adjustment), presented the lower percentage of 2,62%. Therefore, we concluded that model I, AR (1), without the inclusion of intervention dummies, is the best candidate for estimating future values of the FSC-certified area in Latin America.

In Brazil, despite the large area of native forests, the majority of the FSC-certified area refers to forest plantations, of which approximately 60% were already FSC-certified in 2013 (Basso, *et al.,* 2018), in 2025, this percentage should be bigger due the expansion of forest plantations area to support the increasing investments by pulp and paper industries (IBÁ, 2025). Tahvanainen *et al.* (2018) highlight the strong influence of the pulp market on forest development in Uruguay, reporting on the expansion of the Uruguayan pulp industry from when large corporations established operations in that country through 2018, being thus influenced by global markets and their value chains. Similarly, Tricallotis *et al.* (2020) found that, in Chile, forest certification had a much greater impact on the performance of large forest plantation companies, which have a much larger operational footprint than small and medium-sized forest plantation companies and the native forest industry.

The significant intervention dates identified in this study, in the years 2013-2014 and 2017, also lead us to reflect on factors from that period that may have contributed for increasing the behaviour of the series at that specific time periods. As a market tools, forest certification may influence the access to international markets, and therefore, we plot FAO series for Export Quantity and Export Value for chemical wood pulp for South America, from 2013 to 2023 to visualize if any of the intervention year identified could follow significantly the changes in these series (Figure 7).

Figure 7 - Plots of Chemical wood pulp - export quantity (ton) & export value (1000 USD), respectively, from 2013-2023 (FAO, 2025).



Unfortunately, we couldn't proceed with intervention analysis for these series because this is an annual series of 10 values corresponding with our study time series, furthermore, the countries considered by FSC as Latin Americans gathers more countries than the ones from South American. However, it is noticeable the great difference between those FAO series, with export quantities showing a mostly smooth growing tendency while export value presenting sharp fluctuations, reaching its peak in 2018. Both dates found in our intervention analysis are from 2017, suggesting that the heating in chemical wood pulp values since 2016 may had encourage more organizations to obtain FSC certification to enter international markets. Curiously, it is also noticeably that exports reached its lowest value in 2020 followed by continuous growth until 2022, but no intervention points were indicated in our analyses for this year, suggesting that organizations seem to fulfil a long-term commitment by maintaining FSC certified areas despite annual market fluctuations. This behaviour corroborates with Klaric *et. al*. (2024) research in Croatia, evidencing that keep the certification is important for retaining existing customers and attracting new ones, in other words, keep the FSC label is crucial for maintaining competitiveness.

Another possibility we consider was that, coincidentally, two of the observed dates correspond to years in which FSC International General Assemblies were held: in 2014 in Seville, Spain, and in 2017 in Vancouver, Canada. FSC General Assemblies are events where the FSC brand is widely promoted worldwide and people from diverse organizations and fields of knowledge come together to discuss and promote responsible forest management. Considering forest certification as a market tool and the forest plantations as highly important for the certified area in Latin America, greater visibility of the FSC during General Assembly years may have mobilized organizations seeking the benefits of this certification system, fostering the certification of new plantation forest areas or even natural forest.

4. Conclusion

Based on the research carried out, it was possible to analyze the time series of the FSC-certified area in Latin America, develop mathematical models for future forecasting, highlighting the use of exogenous variables as a relevant option to improve the fitness of forecast models. Furthermore, we also identified important dates in FSC´s history that may explain the expansion of certified areas in Latin America, discussing the context of FSC certification in this region.

As a voluntary market tool, forest certification requires investment for implementation and is natural that Global commodity organizations are the main users of the FSC system. Azcárate *et al*. (2020) suggest that providing continuous support (e.g., technical and financial) to promote the long-term certification, especially among smallholder farmers, could be an excellent strategy to increase their resilience and help them overcome difficult economic periods. In the context of forest plantations, which account for most of the certified areas in Latin America, global economic fluctuations in the pulp market may compromise the interest of new forest areas to become FSC certified.

Brazil represents a relevant player in chemical wood pulp production global market. In the world ranking of the largest pulp producers, Brazil continues to occupy second place, the United States leads, with a production of 48 million tons, while it comes to exports, Brazil maintains the global leadership (IBÁ, 2025). The importance of international markets to increase the interest in FSC forest certification seems clear, nevertheless, Basso *et al*. (2018) also showed that if the domestic market cannot absorb certified production, certification will not be attractive to forestry companies due to cost-benefit considerations. In other words, if there is no requirement, demand, or price increase for certified forestry products, the incentive to pursue forest certification tends to diminish.

Furthermore, two years with significant intervention dates coincided with FSC general assemblies, which may also be considered relevant factor in the upward trend in the time series, due its high potential to reach important player in global forest market and influence sustainability approach of forestry sector organizations. Moreover, both adjusted models demonstrated strong predictive potential due to their low MAPE, making both them useful for reference in future planning or comparative analyses, and also showing that FSC reach in Latin America is still shy to contribute significantly with the strategic planning goal to certify 300 million hectares by 2026. Finally, we suggest that future research could delve deeper into specific global and local contexts, using other time series from complementary periods, thus enhancing discussions and knowledge in pursuit of expansion of sustainable forest management.

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