Analysis of Factors Affecting Deforestation in Riau From 2001 To 2023 Using The ARDL Approach

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Abstract. Forests are one of the most important elements for human life. One of Indonesia's problems for decades has been high rates of deforestation. Riau is the province with the highest total deforestation in Indonesia in the last 23 years. The government has implemented various measures to achieve both short-term and long-term targets related to reducing deforestation. Therefore, this study aims to analyze the variables suspected of influencing deforestation in the short and long term using the Autoregressive Distributed Lag. The results of the study indicate that the variables influencing deforestation in Riau Province in the short term are the GDP of the agriculture, forestry, and fisheries sectors and forest and land fires. In the long term, the significant influencing variables are the GDP of the agriculture, forestry, and fisheries sectors, the implementation of Law No. 18 of 2013, and the extent of forest and land fires. Based on these findings, in the short term, the government is expected to transform the agricultural sector economy toward a more sustainable direction and halt the clearing of forest areas for oil palm plantations, especially those conducted through forest burning. In the long term, the government should further strengthen the implementation of the law.
Keyword: ARDL, deforestation, forest, Riau

1. Introduction

Forests are one of the most important and irreplaceable elements for human life. As a vital natural resource, forests play a crucial role for humans, both economically, socially, culturally, and in other aspects. Sunderlin et al state that in developing countries, communities' dependence on forests to meet their basic needs and as a primary natural resource is often high, especially among rural populations [30]. One country that remains highly dependent on forests is Indonesia. Currently, there are 19,410 villages surrounding forests with a population of 48.8 million people whose livelihoods still depend on forest resources as a primary source of income [5].

Indonesia is committed to achieving the Sustainable Development Goals (SDGs), one of which is Goal 15: to protect terrestrial ecosystems. Terrestrial ecosystems are important because they provide various ecosystem services that support human life, ranging from biodiversity, clean water, carbon storage, and clean air [3]. One of the challenges in achieving SDG target 15 is the high rate of deforestation in Indonesia, which is not accompanied by natural regeneration.

Indonesia has been dealing with deforestation for decades. According to data from the World Bank website, between 1990 and 2022, Indonesia lost 17.42% of its forest area [35]. Deforestation has led to several natural disasters, including droughts, floods, landslides, forest fires, and climate change, as well as negative social and economic impacts, including poverty and unemployment [4]. These issues indicate that deforestation in Indonesia has caused alarming conditions.

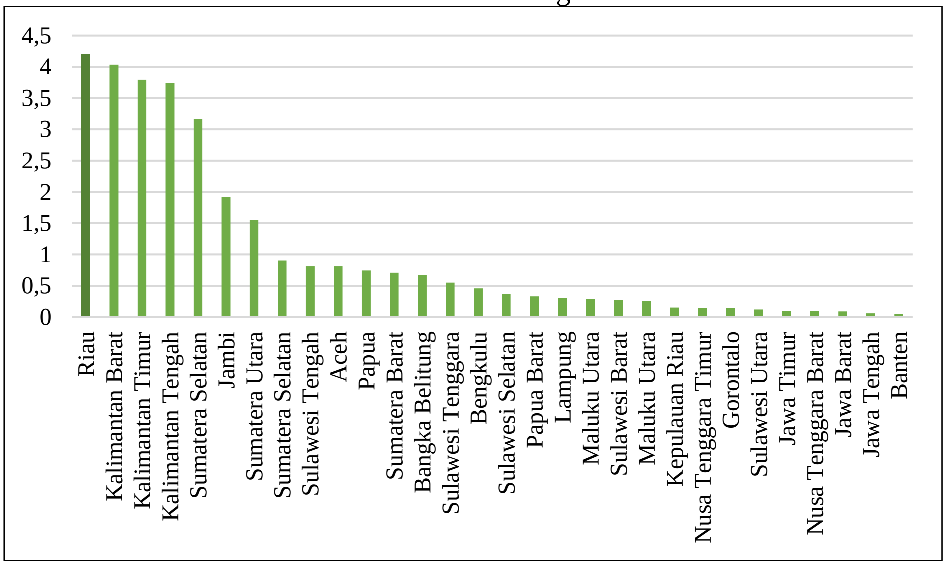


Figure 1. Total deforestation area by province from 2001 to 2023 (million hectares), by [15]

Sumatra, the largest island in western Indonesia, has now lost most of its forests. According to GFW data, Sumatra has experienced the most severe deforestation in Indonesia between 2001 and 2023, with a total deforestation area of 13.9 million hectares [15]. Furthermore, Riau Province has the highest deforestation rate in Indonesia and Sumatra over the past 23 years. According to GFW data in Figure 1, over the past two decades, Riau has lost 4.2 million hectares of its forest cover. This issue requires serious attention from all parties, particularly the Riau Provincial Government.

The government has made various efforts to reduce deforestation in the long and short term. One of the strategies outlined in the 2020-2024 National Medium-Term Development Plan includes a reforestation and enrichment program in 1.97 million hectares of production [26]. Another effort by the government to prevent deforestation is through a bilateral agreement in 2010 with Norway on Reducing Emissions from Deforestation and Degradation (REDD+) and signing a long-term agreement at the Climate Change Summit COP26 to stop deforestation by 2030 [34]. However, despite this, the implementation of the program has not yet met the expectations of the community.

One theory related to the causes of deforestation is the forest transition theory introduced by Mather [20]. The forest transition theory focuses on how forest cover use changes over time. Several studies have been conducted to identify the factors causing deforestation, including studies by Oyekale [22], Ajanaku & Collins [1], Puspitaningrum [27], Destiartono [10], Putra & Oktora [28], and Djaenudin, Oktaviani, Hartoyo & Dwiprabowo [13]. According to Gujarati, the model used to account for the long-term and short-term effects of independent variables on dependent variables is the Autoregressive Distributed Lag model [17]. Therefore, based on the above discussion, the researcher is interested in conducting research to understand the general picture of deforestation and the variables suspected to influence deforestation in Riau Province from 2001 to 2023 and to analyze the influence of these variables, both in the long term and short term, using the Autoregressive Distributed Lag (ARDL) model.

2. Literature Study

According to the FAO, deforestation is the change in land use from forest to other forms of use, or a long-term reduction in tree cover to below a minimum threshold of 10 percent [18]. The use of the term "long-term" by the FAO is still debated and is a complex issue for Indonesia because it has a high rate of vegetation regrowth. Due to differences in methods and definitions of deforestation in each country, the definition of deforestation used in this study refers to the definition from Global Forest Watch (GFW), which is the loss of tree cover for all types of woody plants taller than five meters, whether in mature primary forests, recovered secondary forests, or tree plantations [15].

In this study, the grand theory used is forest transition theory. Forest transition is a theory introduced by Mather in 1992. This theory is used to describe a sequence in which forest cover first declines and reaches a minimum point before slowly increasing and eventually stabilizing [12]. The forest transition theory makes two claims. First, where there are many forests, there will be a lot of deforestation, while in areas with few forests, there will be limited deforestation.

Mather revealed that several factors causing deforestation are population growth, resource value, and demand for forest products and services. Later, Grainger developed the forest transition theory created by Mather [16]. Grainger stated that several causes of deforestation from the forest transition theory are population growth, economic development, government policy, and unsustainable agriculture. The population growth factor approach uses the population growth rate variable. The economic development factor is approached using the GRDP variables for the agriculture, forestry, and fisheries sectors. The government policy factor uses an approach based on the implementation of Law No. 18 of 2013. Meanwhile, the unsustainable agriculture factor uses an approach based on the forest and land fire area variable.

3. Research Method

Data collection

The scope of this study is Riau Province. The data used in this study is secondary data in the form of annual time series data covering a period of 23 years, from 2001 to 2023. Details of the variables used are as follows.

Table 1. Data summary

Symbol	Variable	Unit	Data Source
DEF	Deforestation	Hectare	Global Forest Watch
LPP	Population Growth Rate	Percent	Badan Pusat Statistik
PDRBPERT	GRDP of the Agriculture, Forestry, and Fisheries Sector	Million Rupiah	Badan Pusat Statistik
UURI	Implementation of Law Number 18 of 2013	Dummy	Badan Pemeriksa Keuangan
KARHUTLA	Area of Forest and Land Fires	Hectare	Kementerian Lingkungan Hidup dan Kehutanan

Analysis Method

This study uses two types of analysis methods, descriptive analysis and inferential analysis. Descriptive analysis was used to answer the first objective of the study, which was to determine the general picture of deforestation and the variables suspected of influencing it in line graphs and scatter plots, while inferential analysis was used to answer the second objective of the study, which was to analyze the variables that influenced deforestation in Riau Province in the long and short term from 2001 to 2023.

Inferential analysis was performed using Autoregressive Distributed Lag (ARDL) modeling. The ARDL model is a model that includes current values and past values (lag) of dependent and independent variables [17]. The general form of ARDL (p, q1, q2, …, qk) is as follows [24].

$$Y_t = \alpha + \sum_{i=1}^{p} \lambda_i Y_{t-i} + \sum_{l=1}^{k} \sum_{j=0}^{q_l} \beta_{l,j} X_{l,t-j} + \varepsilon_t \quad (1)$$

The steps in performing ARDL modeling are as follows.

1. Perform a stationarity test using the Augmented Dicky-Fuller (ADF) unit root test.
2. Determine the optimum lag using the Adjusted R2, Akaike Information Criterion (AIC), and Schwarz's information criterion (SIC) criteria.
3. Estimate the ARDL model using the following equation.

$$DEF_t = \alpha + \sum_{i=1}^{p} \lambda_i DEF_{t-i} + \sum_{j=0}^{q_1} \beta_{j1} LPP_{t-j} + \sum_{j=0}^{q_2} \beta_{j2} PDRBPERT_{t-j} + \sum_{j=0}^{q_3} \beta_{j3} UURI_{t-j} + \sum_{j=0}^{q_4} \beta_{j4} \Delta KARHUTLA_{t-j} + \varepsilon_t \quad (2)$$

4. Perform simultaneous testing with the F statistical test and perform partial testing with the t statistical test.
5. Perform classical assumption testing, namely assumptions of normality, homoscedasticity, nonmulticollinearity, and nonautocorrelation. The tests used are the Jarque Berra test for normality, the Breusch-Pagan Godfrey test for homoscedasticity, VIF for non-multicollinearity, and the BG-LM test for non-autocorrelation.
6. Perform cointegration testing with the Bound cointegration test.
7. Estimate the long-run equation (if there is cointegration in the model) with the following equation.

$$DEF_t = \alpha + \beta_1 LPP_t + \beta_2 PDRBPERT_t + \beta_3 UURI_t + \beta_4 KARHUTLA_t \quad (3)$$

8. Estimate the short-term equation using the following equation.

$$\Delta DEF_t = \sum_{i=1}^{p-1} \lambda_i^* \Delta DEF_{t-i} + \sum_{j=0}^{q_1-1} \beta_{j1}^* \Delta LPP_{t-j} + \sum_{j=0}^{q_2-1} \beta_{j2}^* \Delta PDRBPERT_{t-j} + \sum_{j=0}^{q_3-1} \beta_{j3}^* \Delta UURI_{t-j} + \sum_{j=0}^{q_4-1} \beta_{j4}^* \Delta KARHUTLA_{t-j} + \gamma \widehat{EC}_{t-1} + \varepsilon_t \quad (4)$$

4. Result and Discussion

4.1 Overview of Deforestation and Factors Suspected to affectted It in 2001-2023

Over the past decade, countries around the world have begun to care about and focus on stopping and reversing alarming deforestation. One implication of this is the creation of Reducing Emissions from Deforestation and Degradation (REDD+) and the Glasgow Leaders Declaration on Forests and Land Use agreement [34]. The pattern of deforestation and the variables that influence it in Riau Province from 2001 to 2023 is as follows.

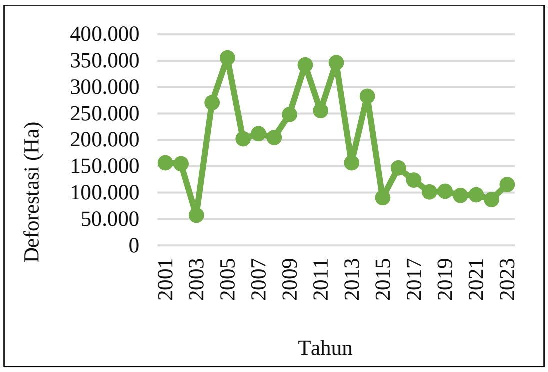


Figure 2. Deforestation Trends.

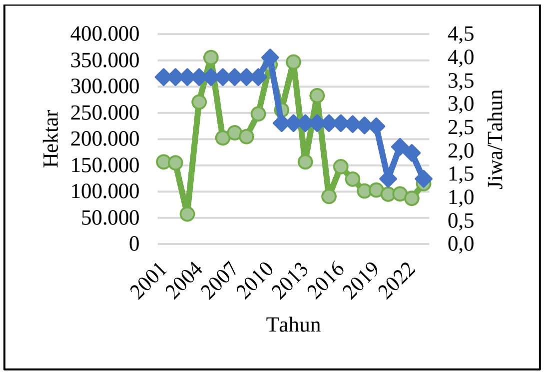
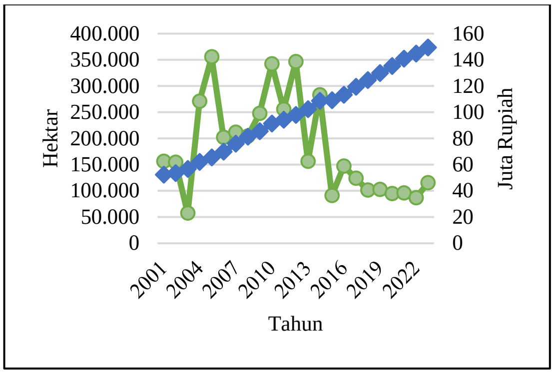


Figure 3. Population Growth Rate Trends

Referring to Figure 2, it can be seen that deforestation in Riau Province during the period 2001 to 2023 fluctuated. The lowest point of deforestation occurred in 2003 at 57,204 hectares. which may have been caused by the fact that after the monetary crisis, the forestry and plantation sectors in Riau experienced stagnant expansion, resulting in delayed forest land conversion [7], and the Indonesian government began to increase its efforts to control concession permits and tighten the moratorium on logging permits [14]. In 2005, deforestation in Riau reached its peak at 355,414 hectares. This was triggered by a long dry season and high intensity of forest and peatland fires [33], as well as increased global demand for CPO (Crude Palm Oil), which led to extensive forest clearing in Riau for oil palm plantations [9].

Figure 3 shows the relationship between population growth and deforestation in Riau Province over the last 23 years. It can be seen that the decline in deforestation (green) began to occur consistently after 2010. This is also in line with the population growth rate in Riau Province (blue), which began to decline in the same period, indicating a positive relationship between population growth and deforestation in Riau Province. Commoner states that rapid population growth, especially in developing countries, will simultaneously increase environmental degradation [2]



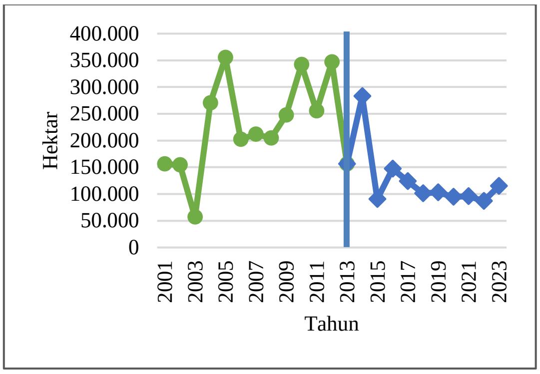


Figure 4. GRDP of The Agriculture, Forestry, dnd Fisheries Sectors Trends

Figure 5. Law No. 18 of 2013 Trends

It can be seen from Figure 4 that the GRDP in the agriculture, forestry, and fisheries sectors in Riau tends to increase and follow an upward trend. Based on a report from the Regional Development Planning Agency, the agriculture, forestry, and fisheries sectors are still the main contributors to the economic structure of Riau Province to date. The GRDP of the agriculture, forestry, and fisheries sector and deforestation in Riau have a negative correlation, whereby the GRDP of the agriculture, forestry, and fisheries sector tends to continue to increase as deforestation in Riau Province decreases [6]. According to Dinilhaq & Azhar, economic growth or an increase in community income can reduce environmental degradation. Environmental degradation will decrease in line with advances in science and technology [12]. Kahuthu states that a negative correlation can occur when there is a shift in information technology from the global to the economy, which has an impact on increasing the effectiveness of the economy [12].

As shown in Figure 5, it can be seen that the government policy, namely Law No. 18 of 2013, only came into effect in 2013 and the impact of this policy is that since 2013, deforestation in Riau Province has tended to continue to decline. The relationship between the implementation of Law No. 18 of 2013 and deforestation in Riau Province is a negative one, whereby when Law No. 18 of 2013 came into effect, deforestation tended to decline. This shows that the policy has been quite effective in curbing deforestation, which had previously fluctuated at a rate of more than 350,000 hectares per year.

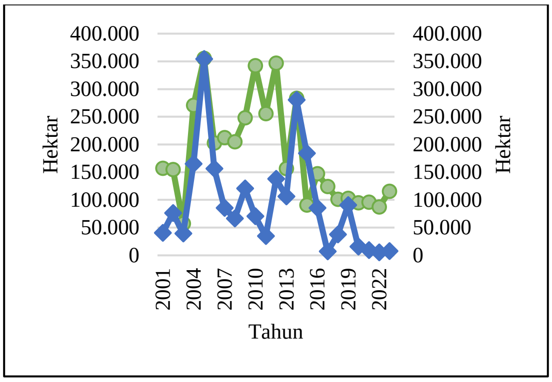


Figure 6. Area of Forest and Land Fires Trends

From Figure 6, it can be seen that the area of forest and land fires (blue) in Riau Province fluctuates significantly every four to five years. Figure 11 also shows that the development of forest and land fire areas and deforestation have very similar patterns. Whenever there is an increase or decrease in the area of forest and land fires, deforestation will also follow, and vice versa. Therefore, it is highly likely that the area of forest and land fires and deforestation have a strong positive correlation.

4.2 Factors Affecting Deforestation in Riau Province in the Long and Short Term from 2001 to 2023

Stationarity Test

The stationarity test in this study uses the Augmented Dicky Fuller (ADF) unit root test. A summary of the stationarity test results is presented in Table 2.

Table 2. Stationarity Test

	Summary of ADF test statistics			
Variable	Level	p-value	First difference	p-value
DEF	-1,4997	0,5141	-7,7432	0,0000*
LPP	-0,7915	0,8018	-6,4689	0,0000*
PDRBPERT	1,1438	0,9965	-5,1444	0,0005*
UURI	-0,9091	0,7657	-4,5826	0,0018*
KARHUTLA	-2.6566	0.0974	-4.9542	0.0008*

*) significant at the 5% significance level

Table 2 shows that all variables are non-stationary at the level. Then, after testing stationarity at the first difference level, it can be seen that all variables are stationary at a significance level of 5 percent.

Determination of Optimum Lag

In this study, the criteria used in determining the optimum lag in the model are Adjusted R^2, AIC, and SIC. These criteria are the default settings of the data processing application, Eviews 12. From the data processing results, the best model obtained is the ARDL (1,1,2,0,2) model.

ARDL Model Estimation

After determining the optimum lag, using the best ARDL model, the following parameter estimation results were obtained.

Table 3. ARDL Model Estimation Result

Variable	Summary of ADF test statistics		
	Coefficient	t-statistics	p-value
C	-478,179.9	-2,2631	0,0471*
DEF(-1)	0,429568	2,9115	0.0155*
LPP	26720,65	0,9335	0,3726
LPP(-1)	38813,94	1,2336	0,2455
PDRBPERT	20029,68	2,4557	0,0339*
PDRBPERT(-1)	-34569,78	-3,2093	0,0093*
PDRBPERT(-2)	18724,98	2,4945	0,0317*
UURI	-168979,4	-4,0240	0,0024*
KARHUTLA	0,915814	6,8129	0,0000*
KARHUTLA(-1)	-0,395397	-2,2515	0,0481*
KARHUTLA(-2)	0,134997	1,0399	0,3229
F-statistics = 11,1272			
Adjusted R^2 = 83,50%			

*) significant at the 5% significance level

The adjusted R2 value of ARDL (1,1,2,0,2) is 83.5, which means that the independent variables in the model have been able to explain 83.5 percent of the diversity of deforestation in Riau Province, while the remaining 16.5 percent is explained by other variables outside the model. In the simultaneous parameter significance test, the F test statistic value was 11.13 with a probability of 0.000362, resulting in the rejection of the null hypothesis at a 5 percent significance level, which means that there is at least one independent variable that affects deforestation.

Based on Table 3, there are several variables that significantly affect deforestation in the applicable year. First, deforestation in the previous year had a significant and positive effect with a coefficient value of 0.4296. This indicates that the problem of deforestation in Riau Province is still high and causes the trend of deforestation to increase every year. Second, the population growth rate in the current year and in the previous year did not have a significant effect on deforestation in the current year.

The variables of GRDP in the agriculture, forestry, and fisheries sectors for the current year, the previous year, and the year before that have a significant effect with coefficients of 20,029.68 for the first lag, -34,569.78 for the second lag, and 18,724.98 for the third lag. A one million rupiah increase in GRDP for the agriculture, forestry, and fisheries sectors in the current year and two years prior will increase deforestation by 20,029.68 hectares and 18,724.98 hectares, respectively. On the other hand, a one million rupiah increase in the GRDP of the agriculture, forestry, and fisheries sector in the previous year will reduce deforestation by 34,569.78 hectares. Each year, the GRDP of the agriculture, forestry, and fisheries sector has a different impact. This indicates that the GRDP data for the agriculture, forestry, and fisheries sector is very dynamic and has a very significant impact on deforestation.

The implementation of Law No. 18 of 2013 has proven to have a significant and negative impact on deforestation in Riau Province. Deforestation in Riau Province when Law No. 18 of 2013 was enacted was 168,979.4 hectares lower than before the law came into effect. This finding is also similar to the results of a study by Kemitraan Indonesia in [23] that the decline in the rate of deforestation is strongly related to the implementation of forest management policies and law enforcement efforts in the forestry sector [23].

The area of forest and land fires in the current year and the previous year had a significant effect with coefficients of 0.9158 and -0.3954, respectively. Meanwhile, the area of forest and land fires in the two previous years did not have an effect on deforestation. This indicates that for every one hectare increase in forest and land fire area in the current year, deforestation will increase by 0.9158 hectares, while in the previous two years it will decrease by 0.3954 hectares. These results are in line with the research by Putra & Oktora, which shows that forest and land fires have been proven to increase deforestation because many parties clear forest land by burning it as it is easy and cheap [28]. However, there is a rebound effect where after forest and land fires increase deforestation, the effect will reverse direction one year later.

Classical Assumption Test

In the modeling process, four assumption tests were conducted, namely normality, homoscedasticity, non-autocorrelation, and non-multicollinearity. The tests used are the Jarque Berra test for normality, the Breusch-Pagan Godfrey test for homoscedasticity, the BG-LM test for non-autocorrelation, and the Variance-inflating Factor (VIF) for non-multicollinearity. The results of the classical assumption tests are shown in Table 4 as follows.

Table 4. Summary of classical assumption tests

Type of Test	Test Statistical Value	*P-value*
Normality	0,1410	0,9319
Homoscetasticity	11,120	0,3482
Non-autocorrelation	2,2552	0,3238

The Variance-inflating Factor (VIF) values for the nonmulticollinearity test are listed in Table 5 as follows.

Table 5. VIF value

Variable	VIF
LPP	5,1075
PDRBPERT	6,8704
UURI	4,1807
KARHUTLA	1,2391

Referring to Tables 4 and 5, using a significance level of 5 percent, it can be concluded that the model has met the assumptions of normality, homoscedasticity, non-autocorrelation, and non-multicollinearity.

Bound Cointegration Test

The Bound test is conducted to determine whether there is a long-term relationship in the model. Based on the test results, the following statistical test values and critical values were obtained.

Table 6. Summary of cointegration test results

F-statistics	α	I(0)	I(1)
5,4964	10%	2,525	3,560
	5%	3,058	4,223
	1%	4,280	5,840

Referring to Table 6, we can see the bound F-statistic value and the test statistic values of Pesaran, Shin, and Smith for 4 independent variables and a sample size of 21 [25]. The F-statistic value obtained is 5.4964, which is greater than the upper critical value at a significance level of 5 percent, which is 4.223. Therefore, at a significance level of 5 percent, it can be concluded that there is cointegration or a long-term relationship in the model so that long-term and short-term equation estimates can be made.

Long-Term Estimation

The results of the cointegration test show that there is a long-term relationship between the variables in the model, so a long-term equation estimation is performed using equation 2, and the results are obtained in Table 7 as follows.

Table 7. Long-term estimation

	Summary of long-term estimation		
Variable	Coefficient	t-statistics	p-value
C	-838.277,1	-1,8531	0,0936
LPP	114.885,9	1,4185	0,1865
PDRBPERT	7.336,351	2.5674	0,0280*
UURI	-296.230,7	-3,2447	0,0088*
KARHUTLA	1,14898	3,1587	0,0102*

*) significant at the 5% significance level

The GRDP of the agriculture, forestry, and fisheries sector in the long term has a significant positive effect with a coefficient value of 7,336.351. This figure shows that in the long term, every increase in the GRDP of the agriculture, forestry, and fisheries sector by 1 million rupiah will increase deforestation by 7,336.351 hectares. This shows that the GRDP of the agriculture, forestry, and fisheries sector has been proven to cause deforestation, in line with the findings of de Barros [11]. These findings further reinforce the theory that economic development causes deforestation.

The GRDP of the agriculture, forestry, and fisheries sectors can increase deforestation because economic development in Riau Province is still supported by oil palm plantations in the agricultural sector [4]. The potential of land resources in this province greatly supports the development of the agricultural sector, especially in the plantation sub-sector. Riau Province is known as the region with the largest oil palm plantation area in Indonesia. The increase in demand for land for plantation expansion in this region has led to a high rate of land or forest conversion (deforestation) to oil palm plantations [31]. Chaily also states that economic development is one of the causes of deforestation, where increased economic development encourages the exploitation of forest natural resources [8].

The implementation of Law No. 18 of 2013 in the long term has a significant negative impact with a coefficient value of 296,230.7. This figure shows that in the long term, on average, deforestation in Riau Province after the enactment of Law No. 18 of 2013 is 296,230.7 hectares lower than before the enactment of the law. This negative impact is due to the fact that with this law in place, the community and private sector have become more fearful and cautious in clearing land and engaging in deforestation. This shows that government policy has proven to reduce deforestation, which is in line with the results of research by the Indonesia Partnership in Pandu [23].

In addition, in the long term, the extent of forest and land fires has a significant positive influence with a coefficient of 1.1490. This figure shows that in the long term, for every 1 hectare increase in the extent of forest and land fires, deforestation will increase by 1.1490 hectares. This finding reinforces the same results in the short term that unsustainable agriculture causes deforestation and is consistent with theory. According to Syaufina, the main factor causing fires in Riau Province is land clearing for palm oil plantations and agriculture. In addition, many people still have minimal knowledge about forest and land fires, so they clear land for agriculture by burning because it is cheap and time-saving [32].

The variable that does not significantly affect deforestation in the long term is the population growth rate. This differs from the results of the ARDL model estimation and differs from the theory. It is possible that deforestation is actually a factor that drives population density in a region, rather than the other way around. Another weakness of Fraser's (1996) argument in Sunderlin & Resosudarmo is that it does not consider various other independent variables that may influence the relationship between population factors and forest cover [29].

Short-Term Estimation

From the results of the ARDL (1,1,2,0,2) model, a short-term equation can be derived to see which variables affect deforestation in Riau Province from 2001 to 2023 in the short term. The short-term equation is obtained as follows

Table 8. Short-term estimation

	Summary of short-term equation estimation		
Variable	Coefficient	t-statistics	p-value
D(LPP)	26.720,65	1,5846	0,1441
D(PDRBPERT)	20.029,68	5,1838	0,0004*
D(PDRBPERT(-1))	-18.724,98	-4,7192	0,0008*
D(KARHUTLA)	0,91581	11,1287	0,0000*
D(KARHUTLA(-1))	-0,13500	-1,6170	0,1370
ECT(-1)	-0,57043	-7,0333	0,0000*

*) significant at the 5% significance level

Referring to Table 8, we can see the variables that influence deforestation in Riau Province from 2001 to 2023. From the short-term estimation results in Table 8, it can be seen that in the short term, the variables that influence deforestation are the GRDP of the agriculture, forestry, and fisheries sectors and the extent of forest and land fires. Meanwhile, the population growth rate does not have a significant effect on deforestation in Riau Province.

When there is a long-term relationship (cointegration) between variables, shocks or fluctuations that occur in the short term will be gradually corrected so that the system can return to long-term equilibrium. This equilibrium adjustment process is corrected by the error correction term component. The error correction term (ECT) coefficient value indicates how quickly the variables in the model return to long-term equilibrium.

The error correction term coefficient or speed of adjustment obtained in this study is significant and negative at -0.57. This figure means that there will be an adjustment of 57 percent in the following period if there is a shock or fluctuation in the current year. This indicates that adjustments occur normally when experiencing short-term shocks and will be corrected in the following period.

Model Stability Test

The final stage in ARDL modeling is the model stability test. This test is used to detect deviations or consistency in regression model estimators over time when regression analysis is used on time series variables. The model stability test is performed using CUSUM and CUSUMQ graphs.

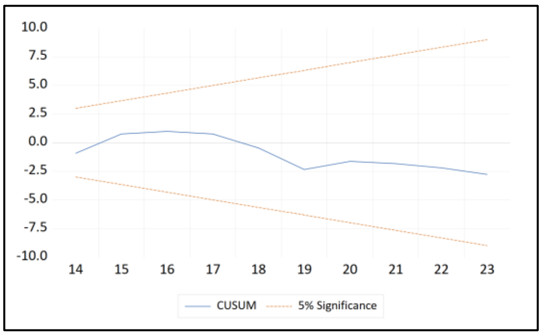


Figure 10. CUSUM graphics

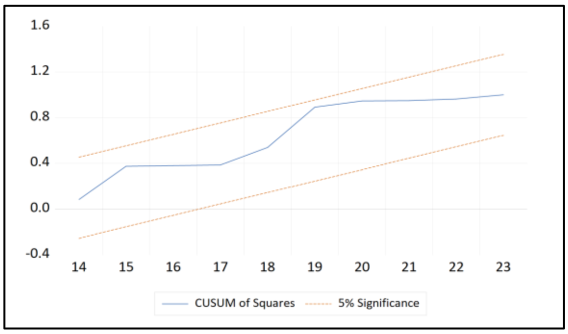


Figure 11. CUSUMQ graphics

From the CUSUM graph in Figure 10, it can be seen that the ARDL (1,1,2,0,2) equation is still within the significance limit. Then, in Figure 11, it can be seen that the ARDL (1,1,2,0,2) equation is still within the CUSUMQ significance limit. Based on the results of the CUSUM and CUSUMQ graphs in Figures 10 and 11, it can be concluded that the coefficients estimated in the ARDL modeling are stable.

5. Conclusion

During the period from 2001 to 2023, deforestation in Riau Province tended to fluctuate significantly, reaching its lowest point in 2003 and its highest point in 2005, and began to decline since 2010. Then, during the same period, the population growth rate tended to decline in line with the decline in deforestation in 2010, so that the two had a positive relationship. In addition, the GRDP of the agriculture, forestry, and fisheries sectors and deforestation had a negative relationship, whereby the GRDP of the agriculture, forestry, and fisheries sectors tended to continue to increase in line with the decline in deforestation. Furthermore, Law No. 18 of 2013 was only enacted in 2013, and since then deforestation has tended to continue to decline, so the two have a negative relationship. Finally, the extent of forest and land fires tends to fluctuate every four to five years and has a pattern very similar to deforestation, so the two have a positive relationship.

Based on the results of analysis using the Autoregressive Distributed Lag (ARDL) model, it was found that in the short term, the variables that influence deforestation in Riau Province are the GRDP of the agriculture, forestry, and fisheries sectors, as well as the extent of forest and land fires. Meanwhile, the variables that influence deforestation in Riau Province in the long term are the GRDP of the agriculture, forestry, and fisheries sectors, the implementation of Law No. 18 of 2013, and the extent of forest and land fires. The analysis results show that the variable that contributes most to the increase in deforestation in the short term is the GRDP of the agricultural sector, while in the long term it is the implementation of Law No. 18 of 2013.

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