AGRARIS: *Journal of Agribusiness and Rural Development Research*

Vol. 8 No. 2 July-December 2022, Pages: 215-230

Article history:
Submitted : March 25th, 2022
Revised : September 19th, 2022
July 25th, 2022
Accepted : September 23rd, 2022

Inaya Cahyaningtyas*, Arini Wahyu Utami, Lestari Rahayu Waluyati
Department of Agricultural Socioeconomics, Faculty of Agriculture, Universitas Gadjah Mada, Indonesia

**) Correspondence email: inaya.cahyaningtyas@mail.ugm.ac.id*

Indonesia's Natural Rubber Productivity and Technically Specified Natural Rubber 20 Export: The Effect of El Nino Southern Oscillation

DOI: https://doi.org/10.18196/agraris.v8i2.14320

ABSTRACT

El Nino Southern Oscillation (ENSO) causes rainfall anomalies, which may disrupt Indonesia's natural rubber production by interfering with the trees' growth and affecting the export volume. This study analyzed the effect of ENSO dynamics on the monthly productivity of natural rubber and Technically Specified Natural Rubber (TSNR) 20 export. Monthly data from January 2006 to December 2019 were collected from the Statistics Indonesia, International Trade Centre (ITC), World Bank, Bank Indonesia, and National Ocean and Atmospheric Administration (NOAA). Descriptive statistics unveiled that strong La Nina increased the average of monthly productivity by 3.37% to 9.68%, while strong El Nino tended to decrease productivity by 1.30% to 9.27%. Moreover, the Vector Error Correction Model (VECM) demonstrated the negative effect of ENSO on Indonesia's natural rubber export, both in the short and long term.

Keywords: El Nino; La Nina; Natural rubber; Productivity; TSNR 20 export

INTRODUCTION

Natural rubber is one of the plantation commodities with a considerable contribution to Indonesia's economy. The report from Statistics Indonesia (2021) revealed that natural rubber contributed 6.13% to the national income of plantation sub-sector in 2019. It also adds to the national income from international trade since 80% of its production is exported. Most types of natural rubber are exported in the form of technically specified natural rubber (TSNR 20/HS 40012220). To maintain the stability of production, water management is crucial. In this regard, climate factors, including rainfall, affect the growth and productivity of natural rubber plants (Daslin, 2013; Susetyo & Hadi, 2012). The average Indonesia rainfall is modulated by climate variability modes, such as El Nino Southern Oscillation (ENSO) (Amirudin, Salimun, Tangang, Juneng, & Zuhairi, 2020; Lestari et al., 2016; Supari et al., 2018).

Rainfall anomalies induced by ENSO can interfere with growth, productivity, and tapping process of rubber plants. ENSO occurs as two distinct phenomena, El Nino, associated with lower rainfall than normal, and La Nina, linked to higher rainfall than normal. Both El Nino and La Nina causes extreme rainfall or flooding and drought throughout Indonesia (Kurniadi, Weller, Min, & Seong, 2021), with the most substantial impact seen during dry season and the weaker impact in wet season. It is strongly tied to the growth of rubber plants in Indonesia, hampered during 1994 and 1997 El Nino as well as 2015 El Nino (Saputra, Stevanus, & Cahyo, 2016). In contrast, there was no interference with rubber growth during the La Nina years (Cahyo, Murti, & Putra, 2020).

In terms of agricultural commodities, ENSO also affects the productivity of oil palm (e.g., Azlan et al., 2016; Stiegler et al., 2019; Suresh, 2013), wheat (Gutierrez, 2017), and other crops (e.g., Anderson, Seager, Baethgen, & Cane, 2017; Iizumi et al., 2014; Nóia Júnior & Sentelhas, 2019). On wider scopes, studies uncovered that ENSO impacted the socioeconomic aspects of society, such as that in South America (Cai et al., 2020), civil conflict (Hsiang, Meng, & Cane, 2011), critical sectors in the society, i.e., water, agriculture, and health (Zebiak et al., 2015), as well as transportation system, such as in California, Hawaii, and the US-affiliated Pacific Islands (Kim, Chowdhury, Pant, Yamashita, & Ghimire, 2021). The link between ENSO and the macroeconomic aspects, including economic growth and inflation, has also been examined (e.g., Cashin, Mohaddes, & Raissi, 2015; Generoso, Couharde, Damette, & Mohaddes, 2020; Smith & Ubilava, 2017).

Previous research analyzed the determinant factors of Indonesia's natural rubber export. Yanita, Yazid, Alamsyah, & Mulyana (2016) discovered that determinant factors of crumb rubber export between 2005 and 2012 consisted of production quantity, exchange rate, and export in previous period. Higher production and lower exchange rate were associated with higher export of natural rubber. In another study on a particular natural rubber importer's country, Sari, Supriana, & Rahmanta (2021) disclosed that the determinant factors of Indonesia's natural rubber export to Japan comprised a positive sign of production and price. Nevertheless, there has been no study on the effect of ENSO climate anomaly on Indonesia's natural rubber export. Therefore, this study assessed the effect of ENSO on the volume of TSNR 20 natural rubber export and computed the monthly productivity differences of natural rubber across the ENSO events.

RESEARCH METHOD

This study utilized secondary data, monthly data from January 2006 to December 2019. The variables of interest included the production quantity and land area of natural rubber, collected from the Statistics Indonesia, the export volume of TSNR 20/SIR 20 (HS 40012220) from the International Trade Centre (ITC) trade map, the international price of natural rubber from the World Bank, and the exchange rate of Indonesian Rupiah (IDR) to US Dollar (USD) from Bank Indonesia (i.e., Indonesia's Central Bank). This study employed the Oceanic Nino Index (ONI) as indicator of El Nino and La Nina occurrence collected by the U.S. National Ocean and Atmospheric Administration (NOAA). The ONI was computed from differences in the sea surface temperature (SST) of the Pacific Ocean Nino region 3.4. El Niño occurs when the ONI is +0.5 or higher, indicating that the corresponding region is much warmer than normal. Meanwhile, La Nina occurs when ONI is -0.5 or lower, meaning that the region is cooler than normal (National Oceanic and Atmospheric Administration [NOAA], 2021).

This study analyzed the differences in productivity across the ENSO phenomena descriptively. The productivity rate was measured by comparing productivity between the same month in different years to determine the difference between months across years. Then, the average monthly productivity changes were compared with the different annual ENSO intensities classified into weak or strong El Nino, weak or strong La Nina, and normal condition. Index level of +0.5 to +1.5/(-0.5 to -1.5) belongs to weak El Nino/(La Nina), while higher than +1.5/(-1.5) indicates strong El Nino/(La Nina).

The influence of ENSO on the volume of natural rubber export was examined using Vector Error Correction Model (VECM) regression. The stages performed before obtaining the VECM results encompassed (1) test for stationarity with unit root test, (2) determination of optimal lag criteria, (3) stability test, (4) cointegration test, and (5) VECM regression. The estimation of the VECM equations is as follows.

Long-term equation:

$$ECT_{t-1} = \beta_0 + \beta_1 Log(Exp\_TSNR20_{t-1}) + \beta_2 Log(Prodtv_{t-1}) + \beta_3 Log(Exc_{t-1}) + \beta_4 Log(Price\_TSNR20_{t-1}) + \beta_5 ONI_{t-1} \quad (1)$$

Short-term equation:

$$\Delta Log(Exp\_TSNR20_t) = \alpha ECT_{t-n} + \beta_0 + \beta_1 \Delta Log(Exp\_TSNR20_{t-n}) + \beta_2 \Delta Log(Prodtv_{t-n}) + \beta_3 \Delta Log(Exc_{t-n}) + \beta_4 \Delta Log(Price\_TSNR20_{t-n}) + \beta_5 \Delta ONI_{t-n} \quad (2)$$

ECT refers to the error correction term or matrix of coefficient cointegration. *Exp_TSNR20* is the export volume of Technically Specified Natural Rubber (ton per hectare). Prodtv represents the productivity of dry natural rubber (ton per hectare). *Exc* is IDR to the USD exchange rate. *Price_TSNR20* implies the international price of TSNR 20 (USD per ton). Meanwhile, the *ONI* serves as the ENSO indicator. Data were analyzed in log form, except the *ONI* data. The symbol of α indicates the coefficient of *ECT*, β_0 refers to a constant, β_1-β_5 are coefficient of all independent variables, t-1 implies the period in one previous month, and n signifies the optimal period on analysis.

RESULTS AND DISCUSSION

ENSO-Monthly Productivity Rate

Rubber trees is an annual plan that begins to produce latex five years after planting. Tapping can be carried out every day until the plants are unproductive. Rubber trees are perennial and sensitive to weather or climatic changes, unlike seasonal crops, of which climatic necessities during cultivation can be easily modified. ENSO consists of normal, La Nina, and El Nino phases of different durations, as described in Table 1.

TABLE 1. LA NINA AND EL NINO EVENTS FROM JANUARY 2006 TO DECEMBER 2019

La Nina Period	ONI Average	Duration (Month)	El Nino Period	ONI Average	Duration (Month)
Jan 2006–Mar 2006	-0.76	3	Sep 2006–Jan 2007	0.76	5
Jun 2007–Jun 2008	-1.09	13	Jul 2009–Mar 2010	1.03	9
Nov 2008–Mar 2009	-0.7	5	Oct 2014–Apr 2016	1.39	19
Jun 2010–May 2011	-1.18	12	Sep 2018–Jun 2019	0.68	10
Juli 2011–Apr 2012	-0.77	10	Nov 2019–Dec 2019	0.5	2
Feb 2014	-0.5	1			
Agt 2016–Dec 2016	-0.62	5			
Oct2017–Apr 2018	-0.79	7			
Total		**56**	**Total**		**45**

SOURCE: NOAA (2021)

From January 2006 to December 2019, El Nino lasted 45 months, and La Nina persisted for 56 months. The most prolonged El Nino occurred for 19 months, from October 2014 to April 2016, with an average ONI of 1.39, considered one of the strongest El Nino recorded since the 1980s. Another El Nino arrived in September 2018 and took place for ten months. The most decisive phase of La Nina happened from June 2010 until May 2011, with a duration of 12 months and an average ONI of -1.18. A month later, La Nina returned, occurring from July 2011 to May 2012, lasting ten months.

ENSO has a seasonal cycle and impacts varied atmospheric circulations (Timmermann et al., 2018). In this case, monthly Indonesia's natural rubber productivity was graphed against the ONI along the 2006 to 2019 study period to exhibit the fluctuation in its productivity during the El Nino and La Nina events. Some notable high productivity of 110 kg per hectare per month or more was associated with La Nina events, as depicted by negative downward bars in Figure 1. On the other hand, El Nino episodes, indicated by positive upward bars, were associated with lower productivity of 60 to 100 kg per hectare per month.

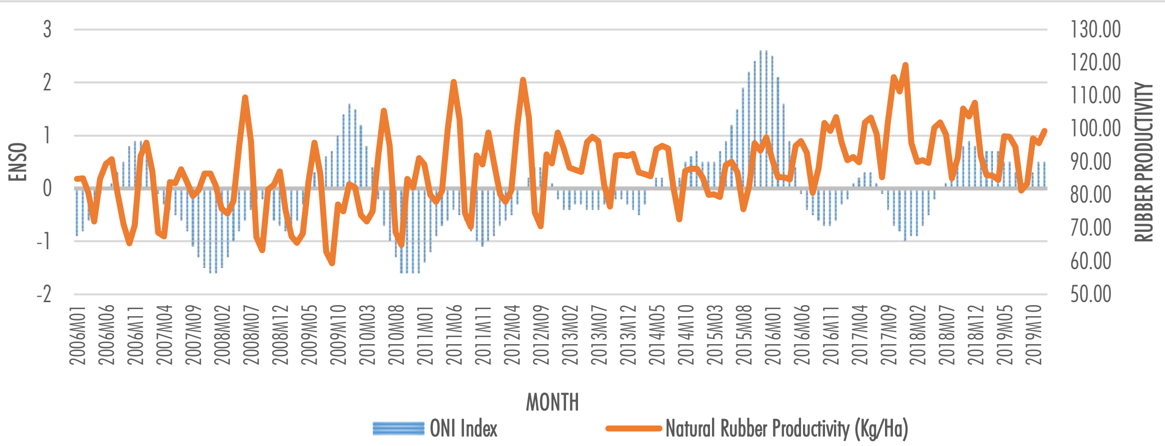

FIGURE 1. MONTHLY NATURAL RUBBER PRODUCTIVITY IN INDONESIA VERSUS THE OCEANIC NINO INDEX, 2006-2019
SOURCE: NOAA (2021); STATISTICS INDONESIA (2021)

Neverthless, it should be noted that La Nina could caused also lower productivity, as occurred in 2008 and 2010, with a monthly productivity of 70 to 80 kg per hectare per month. However, the effect of El Nino could be inconsistent and asymmetries (Ubilava & Abdolrahimi, 2019). For instance, the strong 2015 El Nino was linked to the monthly productivity of 80 to 90 kg per hectare, higher than those from 2009 to 2010 El Nino with only 60 to 80 kg per hectare. The 2015 El Nino was noted as the extreme one, as it fits the description of environmental disasters (Chen, Li, Behera, & Doi, 2016; Meijide et al., 2018; Santoso, Mcphaden, & Cai, 2017). By itself, El Nino is characteristically stronger, if not more extreme, than La Nina (Dommenget, Bayr, & Frauen, 2013; Hsiang & Meng, 2015).

Moreover, Indonesia's natural rubber productivity amounted to 1,095.17 kg per hectare in 2019, or about 91.26 kg per hectare per month (Statistics Indonesia, 2021). The productivity of natural rubber demonstrated seasonal patterns, as exhibited in Figure 2. Average productivity experienced two peak harvests in June and December, while low average productivity occurred from March to April and August to September. Nonetheless, La Nina and El Nino events classified in weak and strong intensities resulted in differences in annual productivity patterns. Seasonal patterns tended to be more regular from 2013 to 2019. However, in 2015, a strong El Nino caused a decrease in average productivity from January to August compared to two years earlier, despite the different production risks in other regions (Qian, Zhao, Zheng, Cao, & Xue, 2020).

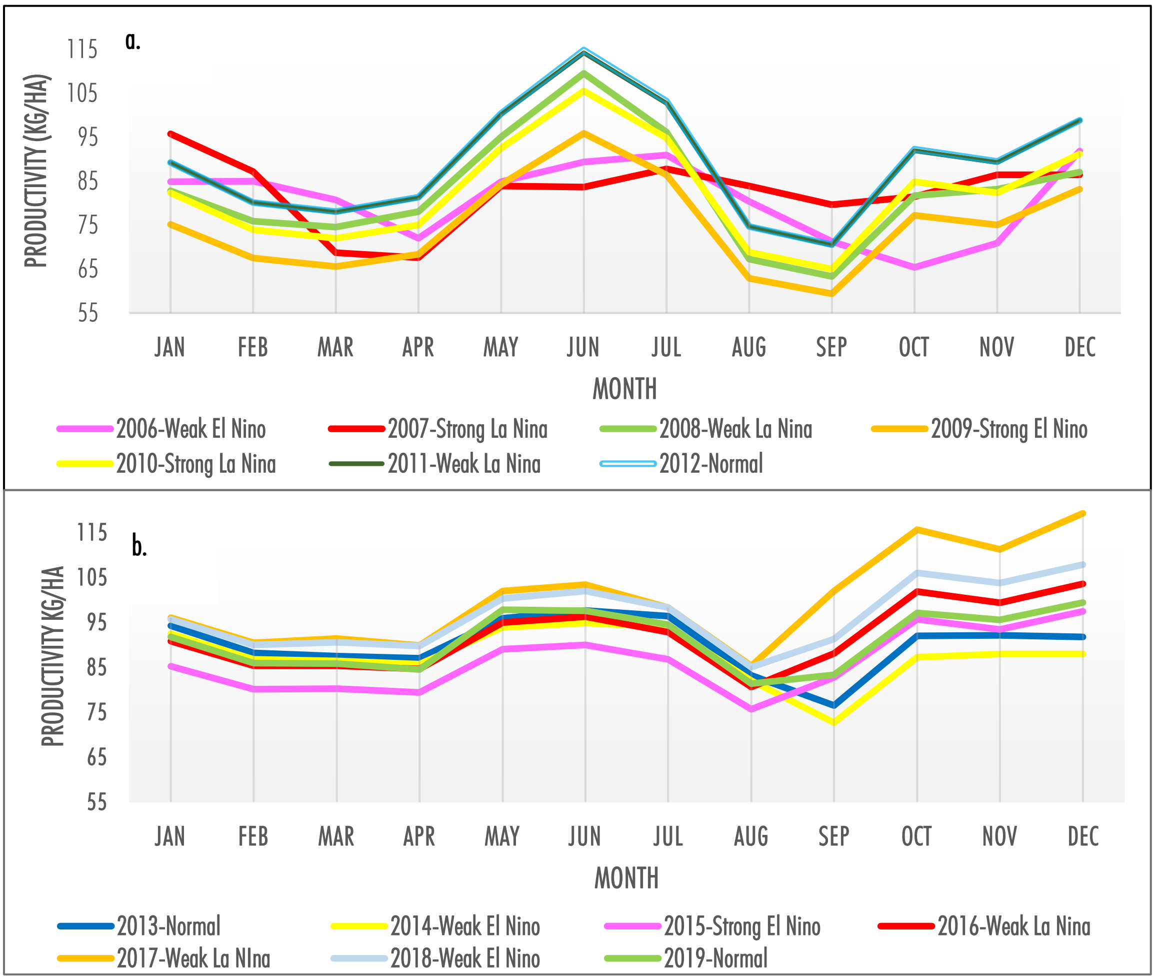

FIGURE 2. MONTHLY PRODUCTIVITY OF NATURAL RUBBER IN INDONESIA (KG PER HECTARE) DIFFERENTIATED BY EL NINO AND LA NINA INTENSITY: (A) IN 2006-2012 AND (B) IN 2013-2019
SOURCE: STATISTICS INDONESIA (2021)

Productivity change analysis described the rate of productivity growth across months. Table 2 displays the analysis results. The average productivity growth rate of natural rubber tended to increase during strong or weak La Nina and decrease following strong or weak El Nino. Strong La Nina raised the average monthly productivity rate by 3.37 to 9.68%, while the strong El Nino event lowered the average monthly productivity by 1.30 to 9.27%. La Nina, causing higher rainfall, could affect the natural rubber supply. Hence, increasing rainfall will enhance the natural rubber supply (Arunwarakorn, Suthiwartnarueput, & Pornchaiwiseskul, 2019).

TABLE 2. NATURAL RUBBER PRODUCTIVITY GROWTH (%)

Year	Event	Month												Average
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
2007	Strong LN	12.90	2.54	-14.95	-6.05	-1.01	-6.42	-3.50	4.42	11.79	24.58	22.01	-5.83	3.37
2008	Weak LN	-13.54	-12.85	8.43	15.58	13.27	30.95	9.64	-19.80	-20.55	0.34	-3.86	0.70	0.69
2009	Strong EN	-9.20	-11.04	-11.92	-12.54	-11.36	-12.47	-10.17	-6.52	-6.21	-5.53	-9.80	-4.46	-9.27
2010	Strong LN	9.49	9.40	9.68	9.77	9.70	10.06	9.80	9.45	9.46	9.94	9.81	9.56	9.68
2011	Weak LN	8.38	8.38	8.32	8.28	8.29	8.23	8.29	8.39	8.39	8.28	8.30	8.38	8.33
2012	Normal	0.00	0.07	0.12	0.24	0.33	0.55	0.41	0.09	0.18	0.48	0.36	0.03	0.24
2013	Normal	5.67	10.08	12.18	6.88	-4.51	-14.97	-6.60	11.39	8.43	-0.35	2.87	-7.18	1.99
2014	Weak EN	-1.87	-1.60	-1.31	-1.42	-2.09	-2.84	-2.39	-1.33	-4.97	-5.13	-4.46	-4.10	-2.79
2015	Strong EN	-7.85	-7.75	-7.14	-7.32	-5.20	-5.19	-7.70	-7.81	13.84	9.58	6.19	10.78	-1.30
2016	Weak LN	6.55	6.54	6.46	6.53	6.61	7.01	6.93	6.54	6.46	6.45	6.36	6.29	6.56
2017	Weak LN	5.69	5.99	7.02	6.18	7.38	7.39	5.96	5.81	15.80	13.51	11.98	15.16	8.99
2018	Weak EN	-0.31	-0.47	-0.96	-0.22	-1.57	-1.36	-0.09	-0.29	-10.52	-8.23	-6.73	-9.57	-3.36
2019	Normal	-4.07	-4.48	-5.13	-5.75	-2.51	-4.34	-3.80	-4.34	-8.67	-8.46	-7.87	-7.83	-5.61

Note: Strong LN = Strong La Nina; Weak LN = Weak La Nina; Strong EN = Strong El Nino; Weak EN = Weak El Nino

In contrast, El Nino, lowering rainfall, could decrease natural rubber productivity, as demonstrated by the 2015 El Nino (Saputra, Stevanus, & Cahyo, 2016). To compare these results to another critical and valuable commodity, lower yield due to El Nino also occurring in palm oil plantations (e.g., Azlan et al., 2016; Khor et al., 2021; Oettli, Behera, & Yamagata, 2018; Stiegler et al., 2019). Khor et al. (2021) computed that the opportunity losses because of El Nino, beginning from 1986 (excluding 2018, 2019), were around USD 9.55 billion, while Oettli et al. (2018) discovered that La Nina was favorable for improving profit. These results are consistent with Selvaraju (2003), examining the impact of ENSO on food grain production, uncovering that total food grain production increased from normal during La Nina.

Vector Error Correction Model (VECM) Estimation

Before running the VECM regression, Augmented-Dickey Fuller (ADF) test was conducted to ensure data stationarity. The VECM required stationary variables in the first difference (I). Table 3 exhibits three insignificant variables at this level. However, all variables of interest were significant in the first difference level (p-value < 0.05).

After all, these variables were stationary, and the subsequent step was determining the optimum lag to be utilized in the regression analysis. Optimal lag testing could take advantage of some information by using Akaike Information Criterion, Schwarz Criterion, and Hannan-

Quin Criterion. The optimum lag length was based on the smallest value among the other lags. The second lag was optimum from AIC, SC, and HQ values marked with asterisks (*) (Table 4).

TABLE 3. RESULTS OF STATIONARY TEST

Variable	Level		First Difference	
	ADF	Probs	ADF	Probs
Log (Exp_TSNR20)	-3.891322***	0.0026	-21.51016***	0.0000
Log (Prodtv)	-1.321500 ns	0.6189	-3.602440***	0.0067
Log (Exc)	-0.832823 ns	0.8069	-10.07921***	0.0000
Log (Price_TSNR20)	-1.857535 ns	0.3518	-9.095177***	0.0000
ONI	-5.223822***	0.0000	-6.043501***	0.0000

Notes: Log (Exp_TSNR20) = Export volume of TSNR 20; Log (Prodtv) = Rubber Productivity; Log (Exc) = Exchange rate; Log (Price_TSNR20) = Price of TSNR 20; ONI = ENSO indicator
***) Significant at the 0.01 alpha, ns) insignificant

TABLE 4. RESULTS FOR LAG LENGTH FOR ENDOGENOUS WITH LAG LENGTH CRITERIA

Lag	LogL	LR	FPE	AIC	SC	HQ
0	95.59894	NA	2.28e-07	-1.104865	-1.010357	-1.066498
1	865.8632	1484.168	2.57e-11	-10.19345	-9.626404	-9.963253
2	1036.428	318.2494	4.37e-12*	-11.96864*	-10.92905*	-11.54660*
3	1058.429	39.70848	4.54e-12	-11.93206	-10.41993	-11.31819
4	1080.086	37.76870*	4.75e-12	-11.89130	-9.906627	-11.08560

Note: (*) indicates lag order selected by the criterion. LR = Sequential Modified LR test statistics (each test at 5% level); FPE = Final Prediction Error; AIC = Akaike Information Criterion; SC = Schwarz Information Criterion; HQ = Hannan-Quinn Information Criterion

Subsequently, the stability test was run, ensuring the modulus was less than one for the regression model to be stable. Table 5 displays less than one modulus on the model. Thus, the second lag fit and the established VARM was stable.

TABLE 5. RESULTS OF THE STABILITY TEST

Root	Modulus
0.986685	0.986685
0.866536 - 0.251219i	0.902217
0.866536 + 0.251219i	0.902217
0.884816	0.884816
0.349903 - 0.685643i	0.769765
0.349903 + 0.685643i	0.769765
0.684584	0.684584
0.423816	0.423816
-0.417256	0.417256
0.093150	0.093150

A cointegration test followed to confirm the short- and long-term equilibrium. Table 6 describes that trace and maximum eigenvalue test indicated three co-integrating equations and might be a long-term equilibrium relationship, confirming the appropriateness of using VECM regression. Table 7 exhibits an ECT coefficient of -0.236381, significant at 0.10 alpha, implying the model's validity. The ECT coefficient determined how quickly the equilibrium was recovered. An ECT of -0.236381 signifies that its equilibrium and the development of the previous TSNR 20 export volume were corrected for the current period of 23.64%.

TABLE 6. COINTEGRATION TEST

UNRESTRICTED COINTEGRATION RANK TEST (TRACE)				
H_0	Eigenvalue	Trace Statistic	Critical Value 0.05	Prob.**
None***	0.570496	221.2900	76.97277	0.0000
At most 1***	0.218516	80.99939	54.07904	0.0000
At most 2 **	0.154764	40.07027	35.19275	0.0138
At most 3 ^{ns}	0.056362	12.15921	20.26184	0.4347
UNRESTRICTED COINTEGRATION RANK TEST (MAXIMUM EIGENVALUE)				
H_0	Eigenvalue	Trace Statistic	Critical Value 0.05	Prob.**
None***	0.570496	140.2906	34.80587	0.0000
At most 1***	0.218516	40.92913	28.58808	0.0008
At most 2***	0.154764	27.91106	22.29962	0.0074
At most 3 ^{ns}	0.056362	9.630022	15.89210	0.3692

Notes: The null hypothesis, H_0 was no-cointegrating vector.
'None' = No co-integrating equation; 'At most (1 to 3)' = The number of co-integrating equations.
***), **) Denotes rejection at the 0.01 and 0.05 alpha, ^{ns}) insignificant
Prob.** MacKinnon-Haug-Michells (1999) p-values

TABLE 7. ESTIMATION OF THE VECTOR ERROR CORRECTION MODEL (VECM)

Variable	Coefficient	Statistics-t	Prob.
Long-Term			
LogExp_TSNR20(-1)	1.000000		
LogProdtv(-1)	-1.556677^{ns}	-12.7314	0.12227
LogExc(-1)	0.516614^{ns}	3.53543	0.14612
LogPrice_TSNR20(-1)	0.027125*	0.50275	0.05395
ONI(-1)	-0.020219**	-1.32340	0.01528
C	2.388028		
Short-Term			
D(LogExp_TSNR20(-1))	-0.487927*	-5.20763	0.09369
D(LogExp_TSNR20(-2))	-0.174404*	-2,08602	0.08361
D(LogProdtv(-1))	-0.286970*	-3.34544	0.08578
D(LogProdtv(-2))	-0.245177^{ns}	-2.35612	0.10406
D(LogExc(-1))	-0.221982^{ns}	0.54001	0.41107
D(LogExc(-2))	-0.251514^{ns}	-0.61428	0.40945
D(LogPrice_TSNR20(-1))	0.128369^{ns}	1.10268	0.11642
D(LogPrice_TSNR20(-2))	0.400922^{ns}	3.48682	0.11498
D(ONI(-1))	0.042009*	0.62032	0.06772
D(ONI(-2))	-0.065942*	-0.06645	0.06645
ECT	-0.236381*	-3.00134	0.07876

Note: LogExp_TSNR20(-1) = TSNR 20 export volume; LogProdtv(-1) = Rubber Productivity; LogExc(-1) = Exchange rate; LogPrice_TSNR20(-1) = Price of TSNR 20; ONI(-1) = ENSO indicator.
All variable were differentiated in the short-term equation and lag 2 was the optimal period. D(LogExp_TSNR20(-1)) = TSNR 20 export volume in lag 1; D(LogExp_TSNR20(-2)) = TSNR 20 export volume in lag 2; D(LogProdtv(-1)) = Rubber productivity in lag 1; D(LogProdtv(-2)) = Rubber productivity in lag 2; D(LogExc(-1)) = Exchange rate at lag 1; D(LogExc(-2)) = Exchange rate at lag 2; D(LogPrice_TSNR20(-1)) = Price of TSNR 20 at lag 1; D(LogPrice_TSNR20(-2)) = Price of TSNR 20 at lag 2; D(ONI(-1)) = ENSO indicator at lag 1; D(ONI(-2)) = ENSO indicator at lag 2; ECT = Error Correction Term.
**) Significant at the 0.05 alpha, *) 0.10 alpha, ^{ns}) insignificant

Table 7 portrays the VECM regression results. Regarding the effect of ENSO on TNSR export volume, an increase of one unit of the ONI, or the tendency of El Nino event, both in the long- and short-term equilibrium, was related to a reduction in the TSNR 20 export volume. A higher ONI indicated the occurrence of El Nino, signifying that El Nino decreased natural rubber export, while La Nina was beneficial for it. It was evidenced by the statistically significant ONI variable in the model, at 5% alpha in the long term and 10% alpha in the short term. One unit increase in the ONI variable (ONI (-1)) in the long term harmed decreasing the TSNR 20 export volume by 100.0201 = 1.05 ton. In the short term, the ONI variable from two previous months (D (ONI (-2)) was associated with declining the TNSR 20 export volume by 1.16 tons.

These results emphasized the effect of non-economic factors, such as El Nino, on natural rubber export. These findings align with Gutierrez (2017), disclosing a negative association between global wheat export and ENSO anomalies. The study, however, discovered that La Nina put a higher burden on wheat export than El Nino. La Nina's highest impact on wheat export was -2.23% after six months following the event, compared to El Nino's highest impact of -0.62% after three months of its occurrence.

ENSO can affect a country's export, especially concerning the national income, including Indonesia. Cashin et al. (2015) uncovered a relative short-term decrease in GDP during El Nino episodes. If traced back to the effect of El Nino on the decline of natural rubber productivity, downstream industries, such as TSNR 20 processing, could be impacted by the availability of natural rubber. It could inhibit export, which consequently lowered the national income. Moreover, excessive heat due to the strong El Nino phase could reduce economic growth (Dell, Jones, & Olken, 2012).

Moreover, the TSNR 20 price variable (LogPrice_TSNR20(-1)) demonstrated a significant and positive value in the long term, meaning that one unit increase in TSNR 20 price, on average, increased the TSNR 20 export volume by 1,064 ton, holding constant other variables. This result is supported by Khin, Bin, Kai, Teng, & Chiun (2019), revealing that when the price dropped by USD 1, the export of natural rubber decreased by up to 30 tons in the ASEAN market. Higher natural rubber price in the world market is an indication of more profit to obtain. It also highlights the importance of natural rubber as one export commodity for the national income (Claudia, Yulianto, & Mawardi, 2016).

Natural rubber export remained steady despite declining the natural rubber price globally (Perdana, 2019). The TSNR 20 price highly affected export since it signaled natural rubber producers of the prospective high profit to earn. Accordingly, it encouraged producers to improve the maintenance of rubber plantations, increasing output and more export (Yanita et al., 2016). On the micro-scale, research by Syarifa, Agustina, Nancy, & Supriadi (2016) revealed that some farmers remained to tap rubber even during falling prices.

Regarding natural rubber productivity, the variable was insignificant in the long-term analysis (LogProdtv (-1)) but negatively significant in the short term on one previous month (D(LogProdtv(-1))). These results contradict Amoro & Shen (2013). The sign on the variable of natural rubber productivity was positive, signifying that an increase in production stimulated an escalation in export. However, this research had a lag time between productivity and export volume. Farmers sometimes reduced the tapping days and delayed the dry rubber trade to the factory or middlemen because of falling prices (Suwardin, 2015). Indeed, it could cause the buildup of dry rubber products to be sold in the following month.

Concerning the effect of TSNR 20 export, the variable was negatively significant in the short term. In other words, the lower export volume in one (D(LogExp_TSNR20(-1))) and two previous months (D(LogExp_TSNR20(-2))) was responded by the higher TSNR export volume. Crumb rubber processing capacity in South Sumatra was only 76.5% fulfilled (Suwardin, 2015). Hence, to optimize the processing and export capacity of natural rubber, the low quality of rubber material, rubber processing technique, and supply chain should be enhanced (Antoni & Tokuda, 2019).

Exchange rate variable depicted insignificant effect in both long (LogExc(-1)) and short term (D(LogExc(-1)) and D(LogExc(-2))). Empirically, it is in line with Klaassen (2004), revealing that the exchange rate had no significant effect on export. In another study, however, the exchange rate affected export due to the depreciation of the Indonesian Rupiah (IDR) currency in the importing country, causing the product price to be lower to improve trade flows (Arumta, Mulyo, & Irham, 2019). On the other hand, another factor excluded in this model was variation in domestic policies across countries. Some policies in some countries, such as using tires, vehicles, and crude oil, could influence the demand for natural rubber. The crude oil price could be an essential factor in the natural rubber price. The input cost of natural rubber products depends on the crude oil price, which is the raw material for synthetic rubber (Fong, Khin, & Lim, 2018). However, although natural rubber is currently less produced and less consumed than synthetic rubber, natural rubber remains irreplaceable by synthetic rubber. In many ways, the advantages of the quality of natural rubber are difficult to match with synthetic rubber (Wahyudy, Khairizal, & Heriyanto, 2018).

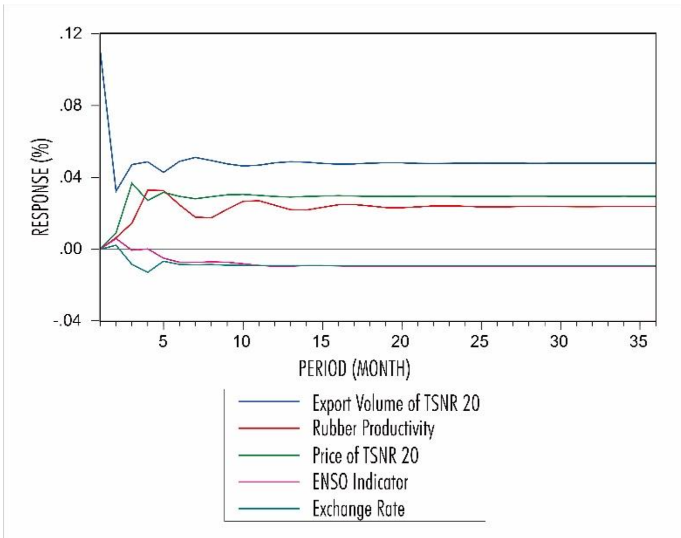

FIGURE 3. IMPULSE RESPONSE FUNCTION (IRF) OF THE TECHNICALLY SPECIFIED NATURAL RUBBER (TSNR) 20 EXPORT VOLUME TO SHOCK AFFECTED BY ENSO, PRODUCTIVITY, EXCHANGE RATE, AND PRICE

Furthermore, Figure 3 presents the impulse response function (IRF), comparing the effect of variables included in the regression. The IRF demonstrated that the shock of the natural rubber export volume by one standard deviation in the first month increased natural rubber export by 11.05% and had not responded to the shock from other variables. In the second month, a shock by ENSO was responded positively by natural rubber export by 0.59%. Then, the response fluctuated until the fifth month, when the export volume negatively responded to the ENSO shock in the next period. The response of natural rubber export to the ENSO shock began to reach balance in the 23rd month, where natural rubber export responded negatively to the shock by 0.96%.

Moreover, variance decomposition analysis helped explain the shock contribution from the natural rubber productivity variable, price, exchange rate, and ENSO to fluctuation in the TSNR 20 export volume. The time frame to forecast this variance decomposition was 36 months (three years). Figure 4 displays that the export shock caused export fluctuation in the first month. In the next 12 months, the export volume was affected by TNSR 20 export by 68.23%, TSNR 20 price by 17.55%, productivity by 11.64%, the exchange rate by 1.60%, and the ONI by 0.97%. However, in the next 36 months, the export volume was influenced by TNSR 20 export by 62.24%, TSNR 20 price by 20.54%, productivity by 13.38%, the exchange rate by 1.99%, and the ONI by 1.86%. The smallest proportion of the ENSO shock disclosed that ENSO in the following few periods did not significantly affect the export shock (Bastianin, Lanza, & Manera, 2018). Fluctuation in the volume of natural rubber export in some periods was predominantly influenced by the export volume rather than other variables.

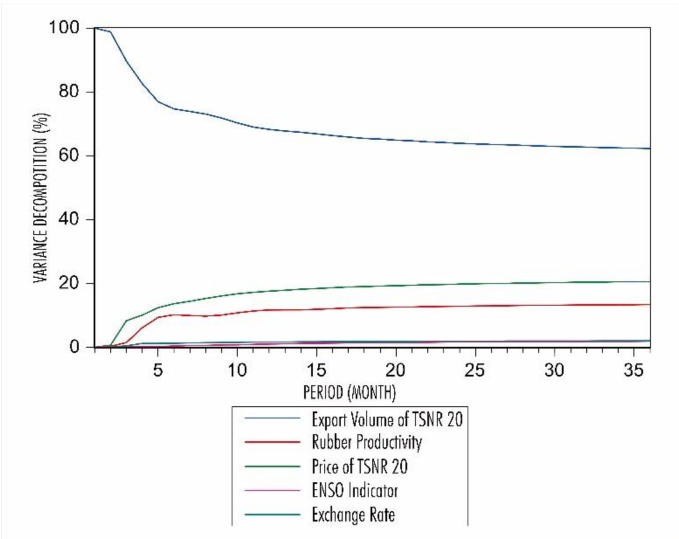

FIGURE 4. VARIANCE DECOMPOSITION (VD) OF THE TECHNICALLY SPECIFIED NATURAL RUBBER (TSNR) 20 EXPORT VOLUME (SHOCK CONTRIBUTION FROM ENSO, PRODUCTIVITY, EXCHANGE RATE, AND PRICE)

CONCLUSION

This study assessed the effect of El Nino Southern Oscillation (ENSO) on natural rubber productivity and the TSNR 20 export volume. A descriptive analysis of natural rubber productivity under the La Nina and El Nino conditions unveiled that La Nina was associated with increased productivity, while El Nino decreased natural rubber productivity. As for the effect of ENSO on the TSNR 20 export volume, in-line results were discovered. The Vector

Error Correction Model (VECM) regression revealed that higher ONI, indicating El Nino, led to the lower TSNR 20 export volume, both in the long and short term.

Following the effect of ENSO on natural rubber productivity, several mitigation efforts could be directed toward using drought-resistant clones and improving water management in rubber plantations, especially during El Nino. Meanwhile, to buffer the shock of ENSO on the export volume, the rubber industry could develop inventory management, specifically during high production or when El Nino is predicted to occur. Expectedly, the inventory could provide the TSNR 20 stock to be exported during low production to lessen the shock on export.

Acknowledgment: The authors are grateful for the support of the Department of Agricultural Socioeconomics, Faculty of Agriculture, Universitas Gadjah Mada (UGM) in providing research facilities.

Authors' contributions: I.C. contributes on conceptualization, data collection, data analysis, writing original manuscript, review and editing manuscript, addressing review comments. A.W.U. is responsible in conceptualization, methodology and writing supervision, review and editing manuscript. L.R.W. is responsible in supervision of data collection and reviewing the manuscript.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

Amirudin, A. A., Salimun, E., Tangang, F., Juneng, L., & Zuhairi, M. (2020). Differential Influences of Teleconnections from the Indian and Pacific Oceans on Rainfall Variability in Southeast Asia. *Atmosphere*, *11*(9). https://doi.org/10.3390/atmos11090886

Amoro, G., & Shen, Y. (2013). The Determinants of Agricultural Export: Cocoa and Rubber in Cote d'Ivoire. *International Journal of Economics and Finance*, *5*(1). https://doi.org/10.5539/ijef.v5n1p228

Anderson, W., Seager, R., Baethgen, W., & Cane, M. (2017). Crop production variability in North and South America forced by life-cycles of the El Niño Southern Oscillation. *Agricultural and Forest Meteorology*, *239*, 151–165. https://doi.org/10.1016/j.agrformet.2017.03.008

Antoni, M., & Tokuda, H. (2019). Identification of Obstacles and Drivers of Smallholder Rubber Farmers to Become Members of A Processing and Marketing Unit in Indonesia. *Applied Economics and Finance*, *6*(2), 79. https://doi.org/10.11114/aef.v6i2.3938

Arumta, N., Mulyo, J. H., & Irham, I. (2019). The Export Determinants of Indonesian Cut Flower in The International Market. *Agro Ekonomi*, *30*(1). https://doi.org/10.22146/ae.44856

Arunwarakorn, S., Suthiwartnarueput, K., & Pornchaiwiseskul, P. (2019). Forecasting equilibrium quantity and price on the world natural rubber market. *Kasetsart Journal of Social Sciences*, *40*(1), 8–16. https://doi.org/10.1016/j.kjss.2017.07.013

Azlan, A. H., LeeChin, T., SohKim, Y., Selvaraja, S., Rohan, R., Ariffin, I., & Palaniappan, S. (2016). Impact of El Niño on palm oil production. *Planter*, *92*(1088), 789–806.

Bastianin, A., Lanza, A., & Manera, M. (2018). Economic impacts of El Niño southern oscillation: evidence from the Colombian coffee market. *Agricultural Economics*, *49*(5), 623–633. https://doi.org/10.1111/agec.12447

Cahyo, A. N., Murti, R. H., & Putra, E. T. S. (2020). Dampak Kekeringan terhadap Proses Fisiologis, Pertumbuhan, dan Hasil Tanaman Karet (Hevea brasiliensis Mull. Arg.). *Warta Perkaretan*, *39*(1), 39–56.

Cai, W., McPhaden, M. J., Grimm, A. M., Rodrigues, R. R., Taschetto, A. S., Garreaud, R. D., ... Vera, C. (2020). Climate impacts of the El Niño–Southern Oscillation on South America. *Nature Reviews Earth & Environment*, *1*(4), 215–231. https://doi.org/10.1038/s43017-020-0040-3

Cashin, P., Mohaddes, K., & Raissi, M. (2015). Fair Weather or Foul? The Macroeconomic Effects of El Niño. In *IMF Working Papers* (Vol. 15). https://doi.org/10.5089/9781475535495.001

Chen, L., Li, T., Behera, S. K., & Doi, T. (2016). Distinctive precursory air–sea signals between regular and super El Niños. *Advances in Atmospheric Sciences*, *33*, 996–1004. https://doi.org/10.1007/s00376-016-5250-8

Claudia, G., Yulianto, E., & Mawardi, M. K. (2016). Pengaruh Produksi Karet Alam Domestik, Harga Karet Alam Internasional, dan Nilai Tukar terhadap Volume Ekspor Karet Alam (Studi Pada Komoditi Karet Alam Indonesia Tahun 2010-2013). *Jurnal Administrasi Bisnis (JAB)*, *35*(1), 165–171.

Daslin, A. (2013). Produktivitas Klon Karet pada berbagai Kondisi Lingkungan di Perkebunan. *AGRIUM: Jurnal Ilmu Pertanian*, *18*(1).

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*, *4*(3), 66–95. https://doi.org/10.1257/mac.4.3.66

Dommenget, D., Bayr, T., & Frauen, C. (2013). Analysis of the non-linearity in the pattern and time evolution of El Niño southern oscillation. *Climate Dynamics*, *40*, 2825–2847. https://doi.org/10.1007/s00382-012-1475-0

Fong, Y. C., Khin, A. A., & Lim, C. S. (2018). Conceptual Review and the Production, Consumption and Price Models of the Natural Rubber Industry in Selected ASEAN Countries and World Market. *Asian Journal of Economic Modelling*, *6*(4), 403–418. https://doi.org/10.18488/journal.8.2018.64.403.418

Generoso, R., Couharde, C., Damette, O., & Mohaddes, K. (2020). The growth effects of el niÑo and la niÑa: Local weather conditions matter. *Annals of Economics and Statistics*, (140), 83–126. https://doi.org/10.15609/ANNAECONSTAT2009.140.0083

Gutierrez, L. (2017). Impacts of El Niño-Southern Oscillation on the wheat market: A global dynamic analysis. *PLoS ONE*, *12*(6). https://doi.org/10.1371/journal.pone.0179086

Hsiang, S. M., & Meng, K. C. (2015). Tropical Economics. *American Economic Review*, *105*(5), 257–261. https://doi.org/10.1257/aer.p20151030

Hsiang, S. M., Meng, K. C., & Cane, M. A. (2011). Civil conflicts are associated with the global climate. *Nature*, *476*, 438–441. https://doi.org/10.1038/nature10311

Iizumi, T., Luo, J. J., Challinor, A. J., Sakurai, G., Yokozawa, M., Sakuma, H., ... Yamagata, T. (2014). Impacts of El Niño Southern Oscillation on the global yields of major crops. *Nature Communications*, *5*, 3712. https://doi.org/10.1038/ncomms4712

Khin, A. A., Bin, R. L. L., Kai, S. B., Teng, K. L. L., & Chiun, F. Y. (2019). Challenges of the Export for Natural Rubber Latex in the ASEAN Market. *IOP Conference Series: Materials Science and Engineering*, *548*, 012024. https://doi.org/10.1088/1757-899X/548/1/012024

Khor, J. F., Ling, L., Yusop, Z., Tan, W. L., Ling, J. L., & Soo, E. Z. X. (2021). Impact of El Niño on Oil Palm Yield in Malaysia. *Agronomy*, *11*(11), 2189. https://doi.org/10.3390/agronomy11112189

Kim, K., Chowdhury, R., Pant, P., Yamashita, E., & Ghimire, J. (2021). Assessment of ENSO risks to support transportation resilience. *Progress in Disaster Science*, *12*, 100196. https://doi.org/10.1016/j.pdisas.2021.100196

Klaassen, F. (2004). Why is it so difficult to find an effect of exchange rate risk on trade? *Journal of International Money and Finance*, *23*(5), 817–839. https://doi.org/10.1016/j.jimonfin.2004.03.009

Kurniadi, A., Weller, E., Min, S. K., & Seong, M. G. (2021). Independent ENSO and IOD impacts on rainfall extremes over Indonesia. *International Journal of Climatology*, *41*(6), 3640–3656. https://doi.org/10.1002/joc.7040

Lestari, S., Hamada, J. I., Syamsudin, F., Sunaryo, Matsumoto, J., & Yamanaka, M. D. (2016). ENSO influences on rainfall extremes around Sulawesi and Maluku Islands in the eastern Indonesian maritime continent. *Scientific Online Letters on the Atmosphere*, *12*(1), 37–41. https://doi.org/10.2151/sola.2016-008

Meijide, A., Badu, C. S., Moyano, F., Tiralla, N., Gunawan, D., & Knohl, A. (2018). Impact of forest conversion to oil palm and rubber plantations on microclimate and the role of the 2015 ENSO event. *Agricultural and Forest Meteorology*, *252*, 208–219. https://doi.org/10.1016/j.agrformet.2018.01.013

National Oceanic and Atmospheric Administration [NOAA]. (2021). *El Nino Southern Oscilliation (ENSO)*. USA. Retrieved from https://www.ncdc.noaa.gov

Nóia Júnior, R. de S., & Sentelhas, P. C. (2019). Soybean-maize off-season double crop system in Brazil as affected by El Niño Southern Oscillation phases. *Agricultural Systems*, *173*, 254–267. https://doi.org/10.1016/j.agsy.2019.03.012

Oettli, P., Behera, S. K., & Yamagata, T. (2018). Climate Based Predictability of Oil Palm Tree Yield in Malaysia. *Scientific Reports*, *8*, 2271. https://doi.org/10.1038/s41598-018-20298-0

Perdana, R. P. (2019). Kinerja Ekonomi Karet dan Strategi Pengembangan Hilirisasinya di Indonesia. *Forum Penelitian Agro Ekonomi*, *37*(1), 25–39. https://doi.org/10.21082/fae.v37n1.2019.25-39

Qian, Y., Zhao, J., Zheng, S., Cao, Y., & Xue, L. (2020). Risk assessment of the global crop loss in ENSO events. *Physics and Chemistry of the Earth*, *116*, 102845. https://doi.org/10.1016/j.pce.2020.102845

Santoso, A., Mcphaden, M. J., & Cai, W. (2017). The Defining Characteristics of ENSO Extremes and the Strong 2015/2016 El Niño. *Reviews of Geophysics*, *55*(4), 1079–1129. https://doi.org/10.1002/2017RG000560

Saputra, J., Stevanus, C. T., & Cahyo, A. N. (2016). The Effect of El-Nino 2015 on the Rubber Plant (Hevea Brasiliensis) Growth in the Experimental Field Sembawa Research Centre. *Widyariset*, *2*(1), 37–46. https://doi.org/10.14203/widyariset.2.1.2016.37-46

Sari, D. K., Supriana, T., & Rahmanta. (2021). Determinant factors of Indonesian rubber export to Japan. *IOP Conference Series: Earth and Environmental Science*, *782*, 022053. https://doi.org/10.1088/1755-1315/782/2/022053

Selvaraju, R. (2003). Impact of El Niño-southern oscillation on Indian foodgrain production. *International Journal of Climatology*, *23*(2), 187–206. https://doi.org/10.1002/joc.869

Smith, S. C., & Ubilava, D. (2017). The El Niño Southern Oscillation and economic growth in the developing world. *Global Environmental Change*, *45*, 151–164. https://doi.org/10.1016/j.gloenvcha.2017.05.007

Statistics Indonesia. (2021). *Statistik Karet Alam Indonesia 2021*. Jakarta: BPS-Statistics Indonesia. Retrieved from https://www.bps.go.id/subject/54/perkebunan.html#subjekViewTab4

Stiegler, C., Meijide, A., Fan, Y., Ali, A. A., June, T., & Knohl, A. (2019). El Niño-Southern Oscillation (ENSO) event reduces CO2 uptake of an Indonesian oil palm plantation. *Biogeosciences*, *16*(14), 2873–2890. https://doi.org/10.5194/bg-16-2873-2019

Supari, Tangang, F., Salimun, E., Aldrian, E., Sopaheluwakan, A., & Juneng, L. (2018). ENSO modulation of seasonal rainfall and extremes in Indonesia. *Climate Dynamics*, *51*, 2559–2580. https://doi.org/10.1007/s00382-017-4028-8

Suresh, K. (2013). Adaptation and mitigation strategies for climate-resilient oil palm. In H. Singh, N. Rao, & K. Shivashankar (Eds.), *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies* (pp. 199–211). India: Springer. https://doi.org/10.1007/978-81-322-0974-4_18

Susetyo, I., & Hadi, H. (2012). Pemodelan Produksi Tanaman Karet Berdasarkan Potensi Klon, Tanah, Dan Iklim. *Jurnal Penelitian Karet*, *30*(1), 23–35. https://doi.org/10.22302/ppk.jpk.v30i1.119

Suwardin, D. (2015). Evaluasi Kinerja Pengelolaan Pabrik Karet Remah: Studi Kasus di Sumatera Selatan. *Jurnal Agro Industri Perkebunan*, *3*(2), 108–121.

Syarifa, L. F., Agustina, D. S., Nancy, C., & Supriadi, M. (2016). Dampak Rendahnya Harga Karet Terhadap Kondisi Sosial Ekonomi Petani Karet Di Sumatera Selatan. *Jurnal Penelitian Karet*, *34*(1), 119–126. https://doi.org/10.22302/jpk.v0i0.218

Timmermann, A., An, S. Il, Kug, J. S., Jin, F. F., Cai, W., Capotondi, A., ... Zhang, X. (2018). El Niño–Southern Oscillation complexity. *Nature*, *559*, 535–545. https://doi.org/10.1038/s41586-018-0252-6

Ubilava, D., & Abdolrahimi, M. (2019). The El Niño impact on maize yields is amplified in lower income teleconnected countries. *Environmental Research Letters*, *14*(5), 054008. https://doi.org/10.1088/1748-9326/ab0cd0

Wahyudy, H. A., Khairizal, & Heriyanto. (2018). Perkembangan Ekspor Karet Alam Indonesia. *Dinamika Pertanian*, *34*(2), 1–8. https://doi.org/10.25299/dp.2018.vol34(2).5409

Yanita, M., Yazid, M., Alamsyah, Z., & Mulyana, A. (2016). Determinant Analysis for Rubber Export in Indonesia. *International Journal of Scientific and Research Publications*, *6*(9), 478–481.

Zebiak, S. E., Orlove, B., Muñoz, Á. G., Vaughan, C., Hansen, J., Troy, T., ... Garvin, S. (2015). Investigating El Niño-Southern Oscillation and society relationships. *Wiley Interdisciplinary Reviews: Climate Change*, *6*(1), 17–34. https://doi.org/10.1002/wcc.294