Rice water total factor productivity growth of West Timor region, Indonesia, 2000-2015: a novel parametric approach

[1]Jonathan E. Koehuan, [2]Bambang Suharto, [2]Gunomo Djoyowasito, [3]Wignyanto

[1] Department of Agricultural Engineering, Christian University of Artha Wacana, Kupang, Indonesia; [2] Department of Agricultural Engineering, Brawijaya University, Malang, Indonesia; [3] Department of Agricultural Industrial Technology, Brawijaya University, Malang, Indonesia. Corresponding author: J. E. Koehuan, jekoehuan@gmail.com

Abstract. Rice water productivity (RWP), a new concept in agricultural water management, is one of the keys to achieve food security in semiarid area like the West Timor region. Information regarding the value and growth of RWP over time is important. Therefore, this research aimed at the estimation of RWP, subsequently estimating the rice water total factor productivity (RWTFP) growth with efficiency change (EFC) and production technology change (TEC) of the West Timor region during the year 2000-2015. In doing so, we utilized secondary climate and crop balanced panel data and also applied stochastic frontier analysis (SFA) using the Cobb-Douglas (CD) and Transcendental Logarithmic (Translog (TRS)) production functions with four types of assumed efficiency distribution models to estimate the RWTFP growth. The results showed that due to the instability of rice production and rice consumptive water use inflicted the fluctuation of RWP with the average was 0.452 kg m^{-3}. Both CD and TRS functions exhibited a constant EFC to all districts. CD functions showed a 3.964% improvement of TEC and RWTFP growth, but TRS showed 0.023% decrease of TEC and RWTFP growth. It is important to improve the TEC while maintaining the EFC to gain positive and sustainable RWTFP growth.
Key Words: Cobb-Douglas, Translog, water productivity, rice, West Timor, total factor productivity.

Introduction. The West Timor region is located in Timor Island, which is part of the East Nusa Tenggara Province of Indonesia, and borders the Republic Democratic of Timor Leste in the east and Australia in the south. The region lies in the area of 14,660 km^2 with the population of 1,650 million in 2015 and a growth rate of 1.65% annually. Most of the population (61.65%) depends on agricultural sector. Borrell et al (1998) and Piggin (2003) explained that the primary foods are corn and rice, which are primarily cultivated in subsistence traditional farming system in the semiarid environment. The El Nino Southern Oscillation also strongly affects the island that caused an extreme long dry season; in the wet season, the timing and intensity of rainfall are erratic, posing a threat to plant growth and production. The World Food Programme (2015) reported that, during the last 10 years, there was a 15.60% increase of paddy farmers, which then increased production, reaching 10% per year. However, in the region, 30% of subdistricts are vulnerable to food security.

It is believed that water availability problem, particularly water scarcity, is a main constraint for food production and security worldwide (Hanjra & Qureshi 2010). In addition, Turral et al (2011) argue that climate variability in semiarid region is worsening potential land and water availability, pressuring the enhancement of agricultural water productivity. Based on the example from China, Kang et al (2017) pointed out that it is strongly advised to increase crop water productivity (CWP) to achieve agricultural development sustainability with the challenge of limited water.

In physical term, CWP is defined as crop production per volume of crop water use. Water productivity includes CWP concept that evolved from the irrigation efficiency concept, which was promoted in 1996 by David Seckler and became the marker for new era of water resource management, the core study of the International Water Management Institute and worldwide (Molden 1997; Giordano et al 2017). Research on CWP has been vastly conducted since then; however, Alauddin & Sharma (2013) as well as Alauddin et al (2014) asserted that most of the studies lack spatial and temporal analyses; therefore, they conducted researches regarding CWP of Bangladeshi rice using panel data in district level for four decades. Moreover, Scheierling & Tréguer (2018), based on their review of CWP study, emphasize that there should be a clear productivity and efficiency conceptual understanding among multidisciplines. It is proposed that the enrichment of methodology such as productivity growth analysis is needed to be applied in CWP studies.

According to Jin et al (2010), traditionally, productivity growth analysis in agricultural sector was estimated solely as residual of output to input growth and interpreted as technological growth with the assumption that decision-making unit (DMU) or firm has operated in full efficiency. In the modern analysis, productivity growth is determined not only by technological progress but also by efficiency change (EFC) that constructs the total factor productivity (TFP). Coelli et al (2005) point out that one of the widely used approaches in efficiency and productivity analyses is the stochastic frontier analysis (SFA). SFA, which was first introduced by Aigner et al (1977) together with Meeusen & van Den Broeck (1977), assumes that the DMU or firm works under its frontier or best possible performance, therefore providing EFC. As a consequence, the estimated TFP consists of EFC and technology change (TEC). As a parametric approach, SFA require production function, and the common forms are Cobb-Douglas (CD) and Transcendental Logarithmic (Translog (TRS)) production functions. The SFA could also be analyzed under assumed efficiency distribution, such as half normal or truncated normal, and can provide the analysis in time-invariant or time-varying environment.

SFA has been widely used in studies conducted by Battese & Coelli (1992), Hossain et al (2012), Silva et al (2016), and Arshad et al (2018) in analyzing the TFP growth of rice production in the developing countries. As far as the authors concern, there were only two studies that discussed the TFP growth of CWP, that of Koehuan et al (2019a), which presented the growth of corn total water productivity, and of Koehuan et al (2019b), which presented the growth of the main crop total water productivity.

The differences between this study and the two previous studies are the following: first, this research is focused on the growth of the rice water TFP (RWTFP); second, the two previous studies used the TRS production function, whereas this study used the improved method with the complement of CD production function, which is another popular functional form of SFA; and, lastly, this study provides a stronger insight equipped with four assumptions of efficiency distribution.

Furthermore, this research aimed to estimate the West Timor rice water productivity (RWP) and, subsequently, the West Timor RWTFP growth with EFC and TEC components. This study also provides recommendation to gain positive growth of RWP.

Material and Method

Time and location. The study was conducted from January 2017 to February 2018 in the West Timor region that consists of four districts and one municipal. The districts are Kupang district, South Central Timor (TTS) district, North Central Timor (TTU) district, and Belu district. The municipal is Kupang municipal, the capital city of the East Nusa Tenggara (NTT) Province of Indonesia. The astronomical location of West Timor is 123°27’40”–125°11’59” east longitude and 08°56’17”–10°21’56” south latitude. The map of the West Timor region is presented in Figure 1.

Data sources and preparation. There were two types of data: climatic and cropping data. The climatic data consisted of monthly rainfall data; monthly minimum, average, and maximum air temperature; monthly average air humidity; and monthly average wind speed at two m height. The cropping data included yearly rice harvested area and yearly rice production. Those data were the secondary data from 2000 to 2015 that were provided by the provincial government statistical bureau (BPS Province). The average rice planting time was provided by Runtunuwu et al (2013), and the paddy crop coefficient was provided by the Water Resources Directorate of Indonesia.

As a parametric approach, data preparation was conducted to get balance panel data with normal distribution. Missing value analysis was carried out to fill the blank data. Rescaled Partial Adjusted Sums was used to get the homogenized climate data. Outlier analysis was applied to normalize cropping data.

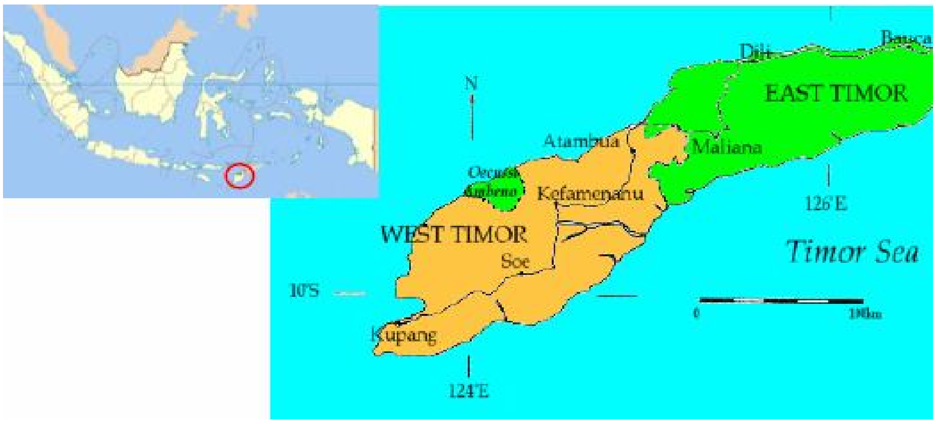

Figure 1. The West Timor region (source: id.wikipedia.org).

Rice water productivity estimation. RWP was estimated as the ratio of rice production per rice water use (RWU) with the equation below:

$$\text{Rice WP} = {\text{Rice Production (kg)}} / {\text{Rice water use (m}^3\text{)}}$$

RWU is a transpiration of rice and evaporation from cropping area that is a potential evapotranspiration multiplied by cropping area. In this study, we used rice harvested area as a proxy for cropping area, which means that the water use estimated only for the successive crop. Water use was calculated based on previous research from developing countries by Vaidyanathan & Sivasubramaniyan (2004), Amarasinghe et al (2007), Alauddin & Sharma (2013), and Alauddin et al (2014) and thus was modified to fulfill the equation below:

$$\text{Rice WU} = HA_{pd} \left[\sum_{j \in mth} \sum_{i \in period} \min\left(Kc_{pd} \times ETo_j, EFFRF_j\right) \times \frac{d_{ij}}{n_j} + \sum_{j \in mth} \sum_{i \in period} \left(Kc_{pd-i} \times ETo_j\right) \times \frac{d_{ij}}{n_j} \right]$$

where HA = harvested area (ha), Kc = crop coefficient, EFFRF = effective rainfall, ETO = potential evapotraspiration, pd = paddy, d_{ij} = days of the j^{th} month in the i^{th} crop growth period, and n_j = the number of days of the j^{th} month.

Potential evapotranspiration (ETO) was calculated based on the Food and Agriculture Organization (FAO) who recommended the Penman–Monteith method, with the help of FAO ETO calculator version 3.2 (Raes 2012). The effective rainfall (EFFRF) was the amount of rainfall that exceeds 75% probability (Alauddin & Sharma 2013; Alauddin et al 2014).

Stochastic frontier method. The rice total water productivity growth was estimated with SFA, a parametric method that required a distribution pattern in data, such as normal distribution, and assumed distribution of efficiency. Arshad et al (2018) argue that SFA is more flexible because it allows a functional form and permits statistical test. However, SFA contains some calculation difficulties.

There are two widely used production functions in SFA: the CD and the TRS. CD is a stricter function than TRS. Regarding efficiency distribution, there are assumptions of half-normal and truncated normal distributions. With regard to efficiency changing over time, there are time-invariant and time-varying models (Coelli et al 2005). Both CD and TRS functional forms included time trend parameters to indicate TEC overtime as suggested by Tsukamoto (2019).

The CD was formulated as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{it} + \beta_2 t + \beta_3 t^2 + v_{it} - u_{it}$$

The TRS functional form is formulated as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{it} + \beta_2 t + 0.5 \beta_3 (\ln X_{it})^2 + \beta_4 (\ln X_{it} t) + 0.5 \beta_5 t^2 + v_{it} - u_{it}$$

where Y = rice production (kg), X = RWU (m^3), v = random error that assumed to be independent and identically distributed (iid) $N(0,\sigma_v^2)$, u = inefficiency, t = year (1, 2, ... 16), and i = districts.

Regarding half-normal efficiency distribution, u_{it} is assumed to be iid $N^+(0,\sigma_u^2)$. With regard to truncated normal efficiency distribution, u_{it} is assumed to be iid $N^+(\mu,\sigma_u^2)$. In terms of efficiency time-invariant model, $u_{it} = u_i$, and in efficiency time-varying model, $u_{it} = u_{it}$ (Battese & Coelli 1992; Coelli et al 2005). To get a better insight into the RWTFP growth, we developed eight models: CD-half-normal-time-invariant (CDHLIN) model, CD-half-normal-time-varying (CDHLVR) model, CD-truncated normal-time-invariant (CDTRIN) model, CD-truncated normal-time-varying (CDTRVR) model, TRS-half-normal-time-invariant (TRHLIN) model, TRS-half-normal-time-varying (TRHLVR) model, TRS-truncated normal-time-invariant (TRTRIN) model, and TRS-truncated normal-time-varying (TRTRVR) model. We applied mean differences to all variables that intended to get the direct estimation of elasticity as suggested by Coelli et al (2003).

Stochastic frontier model selection. Model selection was applied to get the better model to explain the better growth. We used four criteria including Akaike information criteria (AIC), Bayesian information criteria (BIC), mean absolute error (MAE), and mean square error (MSE). AIC and BIC are based on parsimony principles. MAE and MSE explained the absolute and quadratic deviation of the predicted value from observed value, respectively. The best model has the minimum value of the four criteria. The equations of model selection criteria were as follows:

$$AIC = -2 \ln (L) + 2p$$

$$BIC = -2 \ln (L) + p \ln n$$

where L = log likelihood of the model, p = model parameters, and n = observations.

$$MAE = {}^1\!/_n \sum_{j=1}^{n} \left|\ln Y_j - \ln \hat{Y}_j\right|$$

$$MSE = {}^1\!/_n \sum_{j=1}^{n} \left(\ln Y_j - \ln \hat{Y}_j\right)^2$$

where Y_j = observed value, $\hat{Y}_j$ = predicted value, and n = number of observations.

RWTFP growth estimation. The selected models were subsequently used to determine EFC and TEC. RWTFP growth was estimated by a multiplied of EFC and TEC as expressed in the equation below:

$$RWTFPG = EFC \times TEC$$

Efficiency change estimation. EFC was estimated as the residual of observed output to SFA output and fulfills the equation below (Coelli et al 2005; Hossain et al 2012):

$$EF_{it} = {Y_{it}} \Big/ {\exp(X_{it}^{'} \beta + v_{it})} = {\exp(X_{it}^{'}\beta + v_{it} - u_{it})} \Big/ {\exp(X_{it}^{'}\beta + v_{it})} = \exp(-u_{it})$$

$$EFC = EF_{it}/EF_{is}$$

where EF = efficiency, Y = rice production, X = rice water use (RWU), β = model parameter, v = random error, u = inefficiency, i = district, t = curent year, s = previous year (t-1), EFC = efficiency change.

Technology change estimation. TEC was estimated as the geometric mean of partial derivatives of output with respect to time in the previous period(s) and in the period of current year (t) and is expressed as follows (Coelli et al 2005; Hossain et al 2012):

$$TEC = \left\{\left(1+\frac{\partial \ln Y_{it}}{\partial t}\right)\left(1+\frac{\partial \ln Y_{is}}{\partial s}\right)\right\}^{0.5}$$

where TEC = production technology change, Y = rice production (kg), t = current year, s = previous year (t − 1), and i = district.

RWTFP growth calculation was conducted with the help of software Frontier version 4.1 and has three steps: the ordinary least square estimation, a grid search of gamma (γ), and the maximum likelihood estimation (Coelli 1996; Coelli et al 2005; Hossain et al 2012).

Chain indices. Chain indices were employed to capture the productivity growth overtime with the first period of the year 2000 having the value of 1. The chain indices were defined as follows:

$$I_t = \left(X_t / X_{t-1}\right) I_{t-1}$$

where I_t = index at the time t, X_t = value at time t, X_{t-1} = value at time t − 1, and I_{t-1} = index at time t−1.

Result and Discussion

Rice production and water use. During 2000-2015, rice production in five districts of the West Timor region has fluctuated and had a positive trend. The average production reached 67.64 million ton year^{-1} that peaked at 2014, and the lowest production was in 2005. Kupang district has the highest production (46%), while Kupang municipal has the lowest production (1%), as seen in the right side of the axis (secondary axis). The rice production was due to the use of rain water, which showed a fluctuation with positive trends. The average RWU in the region was 157.16 million m^3 that peaked at 2014, and the lowest was at 2005. Kupang district used more water (45%) compared to other districts. It is interesting to note that, during the period, the production increased by 61% with the increase of RWU at 42%, indicating that farmers were more efficient in using water for rice production. Rice production and RWU are depicted in Figure 2.

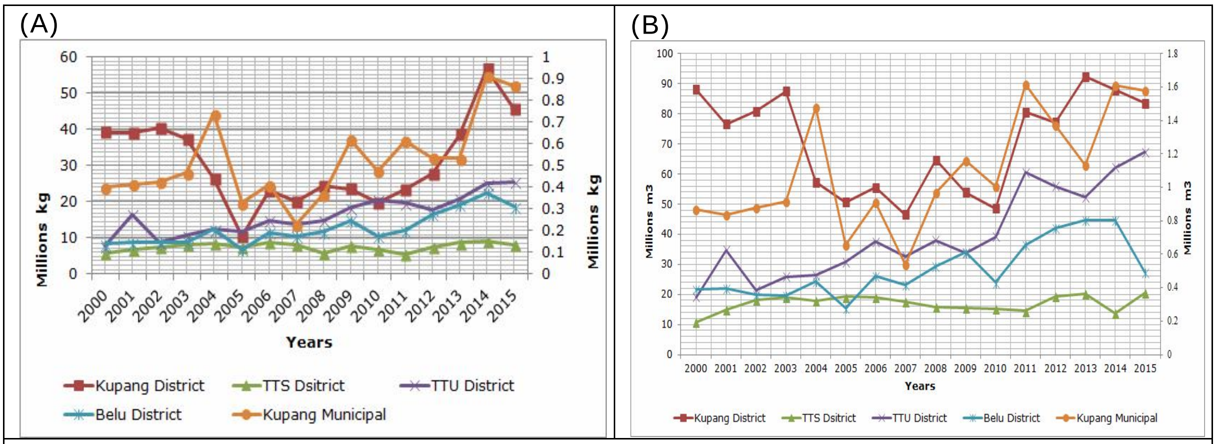

Figure 2. (A) Rice production; (B) rice water use of five districts in the West Timor region during 2000–2015.

Rice water productivity. RWP during 2000–2015, as depicted in Figure 3, exhibited a fluctuation with positive trends, except for TTU district. The average RWP was 0.452 kg m^{-3} in the range of 0.136 kg m^{-3} and 0.980 kg m^{-3}. Kupang municipal, which is a semiurban area with the smallest area and lowest production, had the highest average RWP (0.489±0.169 kg m^{-3}), whereas Kupang district that had the biggest rice harvested areas and the highest rice production in average had the lowest RWP (0.432±0.099 kg m^{-3}). These results highlight the notion of Cai & Rosegrant (2003) that CWP could vary from location to location, depending on many factors such as crop factors, climate factors, water management technology, and other production inputs.

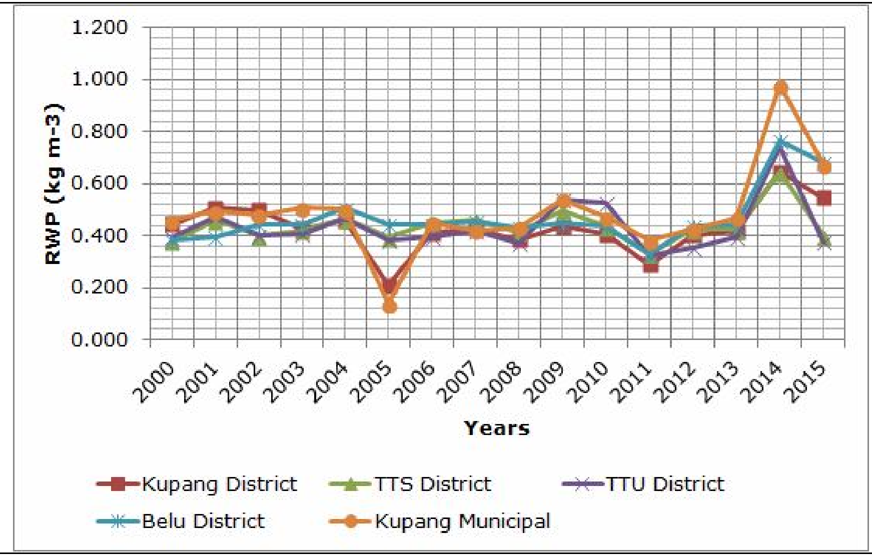

Figure 3. Rice water productivity of five districts in the West Timor region during 2000–2015.

The RWP value was in range with world RWP value ever reported of 0.100 to 2.040 kg m^{-3}. The lowest RWP value was from paddy cultivated in dry land area of Sub-Sahara Africa (Rockström & Barron 2007), whereas the highest RWP value was from paddy cultivated in Indus Ganges Basin (Cai et al 2010). However, the average RWP of the West Timor region during 2000-2015, which was 0.452±0.098 kg m^{-3}, similar with the average Bangladeshi RWP of 0.361 kg m^{-3} reported by Alauddin et al (2014), was considered low compared to the world standard that varies from 0.600 to 1.600 kg m^{-3}, as provided by Zwart & Bastiaanssen (2004).

Model development and selection. The estimation of stochastic frontier models denoted that the four CD models have significant intercept, but none of the TRS models have a significant intercept, implying that other variables that are not included in the models significantly influenced rice production under CD models. All the CD and TRS models expressed a significant effect of RWU, time square, and sigma squared at 1% level, respectively. As might be expected, those results proved that water is one of the prime factors of rice production in semiarid region.

The positive and significant value of time square indicated that the production technology was increasing with nonlinear pattern. The positive and significant value of sigma squared indicated that the cumulative errors were significant. However, those errors were mostly due to random errors, not to efficiency effect, since all the models have low and insignificant gamma value. All CD and TRS models have positive and insignificant time trend values; this showed that production technology had increased insignificantly. In terms of changes in efficiency over time, all models with time-varying assumptions showed negative and insignificant values of the eta parameter, indicating that the efficiency decreases insignificantly over time (Hossain et al 2012).

The CD models excelled in both AIC and BIC criteria; on the other hand, the TRS models excelled in MAE and MSE criteria. The CD models fit the parsimonious principles, which is the simplest model that fits to explain that the data is better. However, based on the deviation from the observed data, the TRS models showed the minimum deviation. The similar value of model criteria described that traditional subsistence agricultural production systems in all districts over time were similar. Table 1 presents the estimated parameters of the eight stochastic border model.

Table 1

The estimated parameters of stochastic frontier models

Parameters	Cob-Douglas function forms				Translog function forms			
	CDHLIN	*CDHLVR*	*CDTRIN*	*CDTRVR*	*TRHLIN*	*TRHLVR*	*TRTRIN*	*TRTRVR*
Intercept	-5.92E-02	-5.92E-02	-5.91E-02	-5.92E-02	-4.64E-02	-4.66E-02	-4.63E-02	-4.66E-02
	(-2.02E-02)***	(3.17E-02)*	(2.99E-02)*	(3.39E-02)*	(5.14E-02)	(3.20E-02)	(3.78E-02)	(3.27E-02)
Ln RWU	9.69E-01	9.69E-01	9.69E-01	9.69E-01	9.58E-01	9.58E-01	9.58E-01	9.58E-01
	(5.83E-03)***	(8.92E-03)***	(1.20E-02)***	(1.23E-02)***	(2.03E-02)***	(1.87E-02)***	(2.02E-02)***	(2.06E-02)***
t	2.16E-03	2.18E-03	2.17E-03	2.17E-03	2.52E-03	2.53E-03	2.52E-03	2.51E-03
	(3.52E-03)	(2.87E-03)	(3.91E-03)	(3.90E-03)	(3.94E-03)	(3.62E-03)	(3.97E-03)	(4.19E-03)
Ln RWU^2	-	-	-	-	-1.24E-02	-1.23E-02	-1.24E-02	-1.24E-02
					(2.04E-02)	(1.52E-02)	(2.01E-02)	(2.05E-02)
Ln RWU x t	-	-	-	-	-4.89E-04	-4.92E-04	-4.94E-04	-4.89E-04
					(2.70E-03)	(2.68E-03)	(2.40E-03)	(2.70E-03)
t^2	2.78E-03	2.78E-03	2.78E-03	2.78E-03	5.68E-03	5.69E-03	5.68E-03	5.69E-03
	(9.07E-04)***	(9.16E-04)***	(9.35E-04)***	(9.06E-04)***	(1.90E-03)***	(1.83E-03)***	(1.89E-03)***	(2.16E-03)**
Sigma	2.56E-02	2.56E-02	2.56E-02	2.56E-02	2.55E-02	2.55E-02	2.55E-02	2.55E-02
squared (σ^2)	(5.24E-03)***	(3.96E-03)***	(3.60E-03)***	(4.43E-03)***	(3.91E-03)***	(3.75E-03)***	(4.09E-03)***	(4.17E-03)***
Gamma (γ)	1.00E-08	1.00E-08	3.36E-07	1.00E-08	1.00E-08	1.00E-08	1.11E-05	1.00E-08
	(2.80E-05)	(4.36E-05)	(9.34E-05)	(7.17E-05)	(5.18E-05)	(3.16E-05)	(3.50E-04)	(7.44E-05)
Mu (μ)	0	0	-1.86E-04	-3.20E-05	0	0	-1.06E-03	-3.19E-05
			(1.54E-01)	(1.21E-01)			(9.17E-02)	(1.39E-01)
Eta (η)	0	-2.39E-02	0	-3.98E-02	0	-6.44E-02	0	-4.01E-02
		(2.55E-01)		(2.96E+00)		(1.94E-01)		(1.86E-01)
Log likelihood	3.30E+01	3.30E+01	3.30E+01	3.30E+01	3.33E+01	3.33E+01	3.33E+01	3.33E+01
AIC	3.004	3.004	3.004	3.004	6.990	6.990	6.990	6.990
BIC	14.914	14.914	14.914	14.914	23.664	23.664	23.664	23.664
MAE	0.121	0.121	0.121	0.121	0.119	0.119	0.119	0.119
MSE	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026

Note: value in parentheses are standard error; *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level.

To study the RWTFP growth with the higher similarities of model indicator value, we slightly depart from model selection criteria to pick up the best model to furthermore study the growth. The selected models were CD and TRS models under half-normal distribution with time-invariant and time-varying models, respectively.

RWTFP growth. RWTFP growth is constructed by the change of EFC and of TEC. EFC and TEC were determined based on the selected models, which were CDHLIN, CDHLVR, TRHLIN, and TRHLVR.

The results showed that the CD and TRS models exhibited different results under time-invariant efficiency. RWTFP growth index by CD in average was 1.002, whereas that by TRS in average was 1.003. The result of the restrictive CD models showed that RWTFP growth in all districts was similar. On the other hand, the less restrictive TRS models captured the different RWTFP growth among districts, with Kupang municipal having better RWTFP growth.

Both CD and TRS functions displayed the same level index of EFC of 1.000, indicating no change in the ability of farmers to utilize water for rice production in the West Timor region during the period of 2000-2015. It also revealed that the capacity of farmers to converse water into rice production was similar across districts and years, explaining that the typical traditional farming system did not change much.

The restricted CD forms showed that the TEC index was similar (1.002) for all districts, whereas the TRS forms showed various indices that ranged between 1.002 and 1.004. The differences of TEC were due to the fact that, in the CD forms, the partial derivative of output with respect to time only considers the model parameter of times, whereas TRS forms not only consider parameters and variables of times but also the value of RWU. It is interesting to note that TEC indices explain the level of rice production of the farming system. The TEC results depicted that there was a slightly improved rice production during 2000-2015 (Coelli et al 2003; Hossain et al 2012). Moreover, in those farming systems, the smallest contributions to total rice production have the better TEC indices. The RWTFP growth based on CD and TRS functional forms with half-normal and time-invariant efficiency effects are presented in Figure 4.

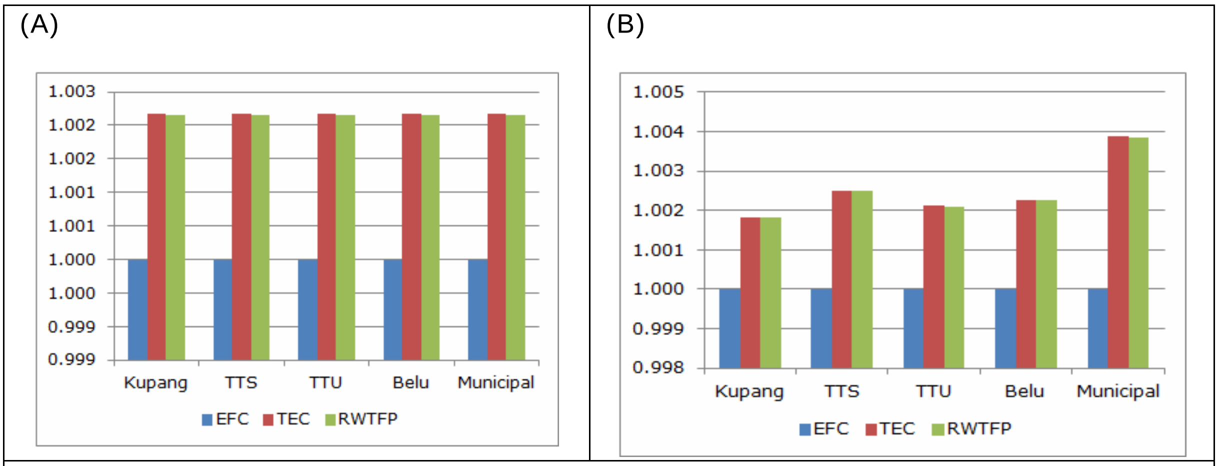

Figure 4. Rice total factor productivity growth with half-normal and time-invariant efficiency distributions. (A) CD function and (B) TRS function of the West Timor region.

In time-varying efficiency models, the changes of EFC, TEC, and RWTFP over time were displayed. With respect to CD and TRS functional forms with half-normal efficiency distribution and time-varying model, the average RWTFP growth indices were 1.002 by CD form and 1.003 by TRS form. Both CD and TRS functional forms estimated the same average EFC indices of 1.000 during the period of 2000–2015. On the other hand, TEC average indices were 1.002 under CD forms and 1.003 under TRS forms (Table 2).

Table 2

Rice water total factor productivity (RWTFP) growth with the component of efficiency change (EFC) and technology change (TEC) from time-varying efficiency models

Year	*EFC*		*TEC*		*RWTFPG*	
	CD	*TRS*	*CD*	*TRS*	*CD*	*TRS*
2000-2001	1.000	1.000	0.983	1.003	0.983	1.003
2001-2002	1.000	1.000	0.985	1.003	0.985	1.003
2002-2003	1.000	1.000	0.988	1.003	0.988	1.003
2003-2004	1.000	1.000	0.991	1.003	0.991	1.003
2004-2005	1.000	1.000	0.994	1.003	0.994	1.003
2005-2006	1.000	1.000	0.997	1.003	0.997	1.003
2006-2007	1.000	1.000	0.999	1.003	0.999	1.003
2007-2008	1.000	1.000	1.002	1.003	1.002	1.003
2008-2009	1.000	1.000	1.005	1.003	1.005	1.003
2009-2010	1.000	1.000	1.008	1.003	1.008	1.003
2010-2011	1.000	1.000	1.011	1.003	1.011	1.002
2011-2012	1.000	1.000	1.013	1.002	1.013	1.002
2012-2013	1.000	1.000	1.016	1.002	1.016	1.002
2013-2014	1.000	1.000	1.019	1.002	1.019	1.002
2014-2015	1.000	1.000	1.022	1.002	1.022	1.002
Mean	1.000	1.000	1.002	1.003	1.002	1.003

Table 2 displays the index value of EFC (1.000), indicating that there was no shift of the capability of farmers in using water for rice production during the period. However, the important point was that the ability of the farming system in maintaining the efficiency level in the erratic rainfall pattern was commendable. Farmers' capacity to transfer water to rice production was considerably high, given the current rice production technology level. The EFC index departed the common perception that traditional farmers in semiarid region were not efficient in utilizing water for agricultural purposes. The fact is that rice farmers inherited the rice cultivation ability from generation to generation, enabling them to wisely make use of water, although improving the efficiency level seems difficult.

TEC was estimated slightly different by CD and TRS functional forms. By the CD form, TEC has the smallest average value and an increasing trend over the period of 2000-2015. On the other hand, the TRS form predicted a higher average value of TEC with a decreasing trend during the period. The pattern exhibited that, from the CD functional estimation, there was an improvement of rice production technology during the period, whereas rice production technology during the period did not improve, especially in the last four years, from TRS functional estimation.

EFC values tend to be constant and TEC values tend to vary causing variations in RWTFC values. This showed that TEC has more influence on changes in RWTFP values. The average growth of RWTFP furthermore resembled the growth of TEC. Moreover, the growth of RWTFP and the component of EFC and TEC from 2000 to 2015 with base period of 2000 showed that there was no EFC change, there were an increase of TEC and RWTFP by 3.964% based on CD functional form, and there were a decrease of 0.023% of TEC and RWTFP under the estimation of TRS functional form as depicted in Figure 5.

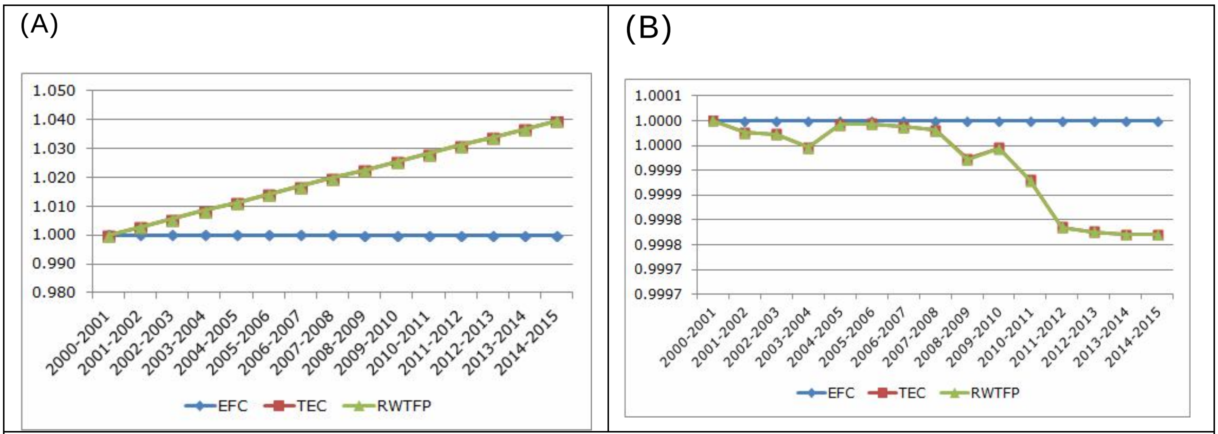

Figure 5. Chain indices of rice water total factor productivity growth. (A) CD function and (B) TRS function of the West Timor region during 2000–2015.

The RWTFP growth is below the average growth rate of RWP in Bangladesh from 1991 to 2004, which reached 35% (Alauddin et al 2014). However, the RWTFP growth showed a resemblant pattern to the TFP of corn water (CWTFP) reported by Koehuan et al (2019a) that was analyzed using the TRS production function with truncated normal and time-varying model, which showed a 5.95% reduction during the same period. Additionally, by employing the TRS production function with truncated normal and time-varying model, Koehuan et al (2019b) showed that the growth of the main food water total factor productivity (MFWTFP) increased by 1.593% during the same period.

In terms of district RWTFP growth during 2000-2015, both CD and TRS functional forms presented resembled results with time-invariant models. The CD and TRS forms estimated the similar average EFC index of 1.000 with differences in the average TEC index. The CD functional form under half-normal and time-varying efficiency estimated equal TEC index of 1.002 that generates the equal RWTFP growth index of 1.002 for all districts. On the other hand, the TRS functional form with half-normal and time-varying efficiency predicted the average TEC indices between 1.002 and 1.004. The differences in the average TEC indices generate the difference of average RWTFP growth indices in ranged of 1.002-1.004. The RWTFP growth of the districts based on half-normal and time-varying models was presented in Figure 6.

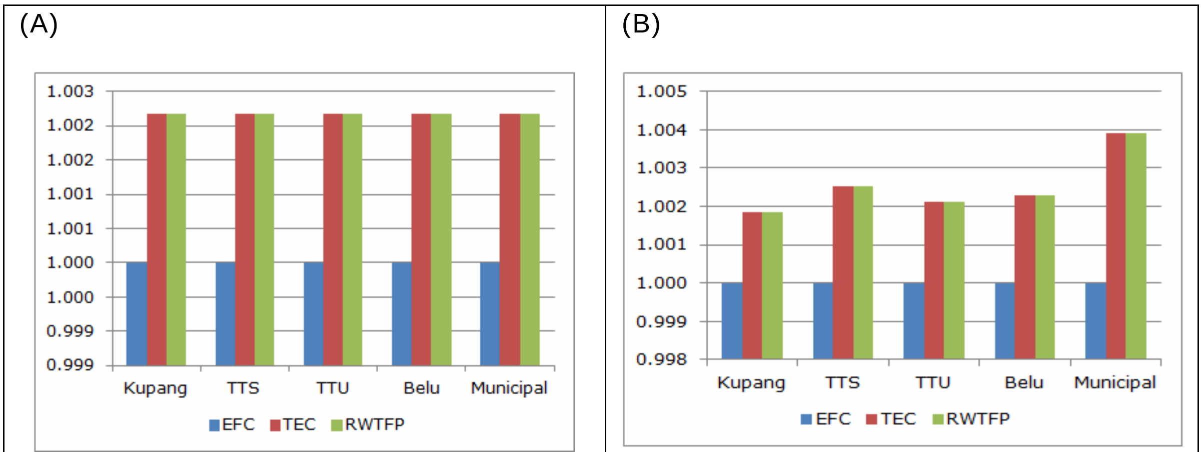

Figure 6. Districts' rice total factor productivity growth with half-normal efficiency distribution and time-varying model. (A) Cobb-Douglas function and (B) Translog function.

The result showed that similarities among districts were contrast with Bangladeshi RWP with wide difference among districts as reported by Alauddin & Sharma (2013) and Alauddin et al (2014). The variations were due to the longer period of time and more districts in the Bangladeshi RWP analysis, which captured more diversity. However, the

Bangladeshi RWP research merely provided the RWTFP growth, in this study we improved it with RWTFP components namely EFC and TEC.

Furthermore, the similar value of EFC index pointed out that the ability of farmers in using water for rice production across the districts in the West Timor region was equal. There was no distinction among districts of the West Timor region. It is interesting to note that, based on TRS forms, the smallest the contribution to rice production, the better the growth index of TEC and RWTFP. This result showed that, in the RWP context, better growth index not only determined the higher rice production but also the less RWU. Kupang municipal and TTS district farmers produce less rice but use water more efficient during 2000-2015. In addition, according to Koehuan et al (2019a) and Koehuan et al (2019b), Kupang municipal also performs better in CWTFP growth as well as MFWTFP growth under TRS production function with truncated normal and time-varying efficiency models.

Rice cultivation in semiarid areas dominated by small-holder farming poses some challenging and ample opportunity not only in increasing CWP but also in strengthening food security, leading livelihood improvement (Cai & Rosegrant 2003; Rockström & Barron 2007; Giordano et al 2017). In this case, Rockström & Barron (2007) point out two strategies: to enhance the plant capacity to uptake water and to increase crop water availability. The strategies are achieved by the proper management of soil and water. Moreover, based on the experience of China in simultaneously increasing rice yield and using water more efficient, Yang (2015) proposed a breeding nitrogen-efficient uptake cultivar coupling with the improvement of harvested index.

Conclusions. Rice, as main food for the population of the semiarid region of West Timor, has been cultivated primarily in the traditional subsistence farming system, which resulted in a fluctuation of either production or water use. These fluctuations subsequently generate the fluctuation of RWP over time and among the districts. Although the average RWP in the West Timor region during 2000-2015 has increased, it was still lower than global standard.

RWTFP growth, estimated by a parametric approach using SFA with CD and TRS production functions, revealed that there is no prominent distinction whether the efficiency distribution was half-normal or truncated normal as well as whether the efficiency was time-invariant or time-varying, proving that the typical dominated traditional farming system tend to be indistinguishable over time and locations. RWTFP growth indices were slightly different between CD form and TRS form. Despite that, both functional forms depicted the same substantial but unchanged EFC index during 2000-2015 in all districts. The TRS explained more variation in TEC indices during the period, besides that the smallest rice producer had a better growth of TEC index and RWTFP index.

The improvement of RWTFP growth is inevitable with broader objective including the increase of food security and sustainability. In the case of the West Timor region, improving first the TEC, which is the numerator of RWP, while simultaneously maintaining the RWU efficiency (EFC), which is the denominator of RWP, is suggested.

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Authors:
Jonathan E. Koehuan, Department of Agricultural Engineering, Christian University of Artha Wacana, Jl. Adi Sucipto No. 147, Oesapa, Kota Kupang, NTT 85228, Indonesia, e-mail: jekoehuan@gmail.com; jonathankoehuan@yahoo.com; jekoehuan@ukaw.ac.id
Bambang Suharto, Department of Agricultural Engineering, Brawijaya University, Jl. Veteran Malang, Jawa Timur 65145, Indonesia, e-mail: bambangs@ub.ac.id
Gunomo Djoyowasito, Department of Agricultural Engineering, Brawijaya University, Jl. Veteran Malang, Jawa Timur 65145, Indonesia, e-mail: djoyowasitogunomo@yahoo.com
Wignyanto, Department of Agricultural Industrial Technology, Brawijaya University, Jl. Veteran Malang, Jawa Timur 65145, Indonesia, e-mail: wignyanto@ub.ac.id

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