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Staple food water total factor productivity growth towards food security in West Timor, Indonesia

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STAPLE FOOD WATER TOTAL FACTOR PRODUCTIVITY GROWTH TOWARDS FOOD SECURITY IN WEST TIMOR- INDONESIA

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Abstract

One of the prominent ways to boost food security in semi arid region like West Timor where water is scarce is by the increasing of food water productivity or to increase food production with less water. This study made a remarkable contribution with taking into consideration food water TFP growth with its components of efficiency change and technology change. This study furthermore focused on the estimation of food water productivity, the estimation of food water TFP growth and the implication to food security. To doing so, 16 years secondary balanced panel data of climate and non climate data were used. We applied FAO Penman-Monteith method in estimating crop water use as the denominator of water productivity subsequently stochastic frontier analysis- Malmquist index in estimating food water TFP growth and its decomposition. The results showed that during 2000-2015, food water productivity in terms of production per crop water use showed a fluctuated trend, with averaging WP_{Paddy}, WP_{Corn} and WP_{Food} which is aggregated of paddy and corn were 0.459 kg rice/m^3, 0.455 kg equivalen rice /m^3 and 0.458 kg rice/m^3 respectively. Averaging TFP growth for $WP_{Paddy,}$ $WP_{Corn\ and}$ WP_{Food} were 1.003, 1.014 and 1.015 respectively. It is important to note that the TFP growths were mostly influenced by technology growth rather than efficiency growth. The municipal of Kupang had the higher TFP growth compared to other districts. Therefore the improvement in production

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technology, better access to production input, and enhancing farms management are the key to sustain food security in West Timor.

Keywords:*stochastic frontier analysis, technology change***,** *corn, rice, water productivity*

Introduction

Nowadays most of developing countries facing a food security challenge due to the rapid population growth coupling with natural resources degradation and uncertainty in climate change. Those negative effects could demote agricultural production leading to widening the food security gap. Water is the prominent input in agricultural production, it is imperative to boost agricultural water management through improving agricultural water efficiency so the production could be improved with proper amount of water (Rosegrant *et al*., 2009; Brauman *et al*., 2013).

With regard to semi arid region like West Timor which a part of East Nusa Tenggara (NTT) Province of Indonesia, the staple food are paddy (*Oryza sativa* L.) and corn (*Zea mays* L.). Agriculture is main source of living for the population (61%). However, subsistence traditional farming in dry land environment dominating the agriculture practices, only about 10% doing a commercial farming (Therik 2000; Foenay 2000; Piggin 2003). Corn cultivation that mostly in dry land areas (*ladang*, *kebun*) dominated paddy cultivation that mostly planting in wet land areas (*sawah*) that is more intensive compared to corn cultivation. In addition, more than a half of farmers experience climate change and natural disaster of drought and high intensity rain, 48.47% of paddy households and 57.51% of corn households (BPS NTT 2016).

Despite there is an increasing of food production WFP (2015) reported that there is a 30% of sub districts in West Timor categorized as vulnerable to food security.

Dealing with the problems mention above it is suggested to increase crop yield with the reduction of water use or by using the same amount of water to produce more food by means the increasing of crop water productivity (CWP) (Kang *et al*., 2017). Molden (1997), presented the first prominent research in water productivity. Water productivity that evolves from previous water use efficiency concept is defined as the marketable crop yield per actual evapotranspiration (ETa) (Zwart and Bastiaanssen 2004). ETa in large areas with continuous measure facing considerable difficulties furthermore it is suggested to estimate by indirect method using crop water use (CWU). CWU is the volume of water that transpires by crops and evaporates from crop surrounding areas during the growing periods (Amarasinghe *et al*., 2007; Sharma *et al*., 2015).

There are considerable researches regarding CWP in the developing countries, however very little discussion regarding temporal and spatial growth. The works of Alauddin and Sharma (2013) and Alauddin *et al*., (2014)by using panel data furthermore provide the rice water productivity growth of 21 Bangladesh districts over 37 years. Mean rice water productivity in Bangladesh is 0.361 kg/m^3 of CWU with the average annual growth of 2.14%. Technology dispersion is the prime factor determining the WP variation among the districts. Additionally, there is a need to sustain the growth with better provision of agricultural inputs, increasing research and development, and institutional support.

However, there is still not clear scientific information regarding crop water total factor productivity growth that constructed by efficiency change and technology change. Likewise concerning crop water productivity growth that related to food security in semi arid areas of developing countries where most of the population depending heavily on traditional agricultural. This study is intended to fill the gap furthermore to contribute to the water productivity and food security researches.

In terms of productivity growth analysis nowadays a total factor productivity (TFP) growth is more robust compared to traditional productivity analysis. Traditional productivity analysis limit to study the impact of technology growth under the assumption of the production unit operate in efficient form. TFP analysis on the other hand provides more robust result due to the TFP growth that constructed not only by technology change(TEC) but also by efficiency change (EFC). The positive growth of TFP is gained by an increasing of production frontier or by the increasing of production efficiency that catching up with given production technology. Additionally, Malmquist Index is widely used to specify the TFP growth and its decomposition to TEC and EFC (Coelli *et al*., 2005; Chen *et al*., 2017).

Malmquist index furthermore could be determined by both non parametric approached and parametric approached. The stochastic frontier analysis (SFA) is classified in the parametric approached with the advantages include the results is minimal in bias because the use of parametric data, the efficiency component is extracted from random variable, its using functional forms that flexible in define systems under study, and that enable to conduct statistical test (Coelli *et al*., 2005).

This study furthermore focused on the estimation CWU leading to the estimation of paddy water productivity (WP_{Paddy}), corn water productivity (WP_{Corn}) and food water productivity (WP_{Food}) that was the aggregated of paddy and corn water productivity. Subsequently this study had estimated TFP growth with the decomposition of EFC and TEC as well as the implications of WP_{Food} TFP growth towards food security.

Materials and Methods

The Study Area

This study was conducted at West Timor that astronomically located at 123^0 27' 40" – 125^0 11' 59" East Longitude and 08^0 56' 17" – 10^0 21' 56" South Latitude. The region has a municipal (Kupang) that the capital city of The East Nusa Tenggara (NTT) Province and four districts namely Kupang district, South Central Timor (TTS) district, North Central Timor district (TTU) and Belu district.

Data Sources and Preparations

This study was use climate and non climate balance panel data of 2000 to 2105. The climate data included monthly rainfall, monthly average, minimum and maximum air temperature; monthly wind speed, monthly average humidity. The Rescaled adjusted partial sums (RAPS) homogeneity test was applied, the test more suitable for developing countries climate stations. The non climate data were crop harvested data, crop production data, and crop price data that provided by NTT

Province bureau of statistics (BPS NTT). Additionally, average crop planting time provided by (Runtunuwu *et al*., 2013) and crop coefficient (Kc) that was suitable with Indonesian condition that provided by Indonesian water resources bureau. In order to get the balance panel data that had a normal distribution, then the missing value analysis with Lagrange interpolation, outlier analysis and a Shapiro-Wilk test were carried out.

Crop Water Productivity Estimation

There were three steps in conducted the CWP estimation. Firstly, the climate data was utilized to estimate the potential evapotranspiration (ETo) based on FAO Penman-Monteith (FAO-PM) method with the help of FAO-ETo calculator (Allen 2006; Raes 2012). The effective rainfall furthermore was estimated by 75% probability as suggested by (Alauddin and Sharma 2013; Alauddin *et al*., 2014; Amarasinghe*et al*., 2005; Amarasinghe *et al*., 2007). Secondly to interpret the CWU based on the method by (Alauddin and Sharma 2013; Alauddin *et al*., 2014; Amarasinghe *et al*., 2007; Amarasinghe *et al*., 2014, Sharma *et al*., 2015) with some adjustment to meet with available data and unlike previous method that put forward irrigation type as bases, in this study we set the crops as the bases. Thirdly, crops water productivity (CWP) was estimated based on the equations below.

$$CWP = \text{Crop Production (kg)} / \text{CWU (m}^3\text{)}$$

In order to have a staple food production as a single input that composed from rice and corn productions, we were converse corn production into equivalent rice production by using local price comparison. This method was modified form Molden *et al*. (1998), as formulated below:

$$\text{Rice equivalent}_t = \left(\text{Corn price}_t / \text{Rice price}_t\right)\ (\text{Corn production}_t)$$

$$\text{WP}_{\text{Food, t}} = (\text{Rice production}_t + \text{Rice equivalent}_t)/\text{CWU}_{\text{Food,t}}$$

Total Factor Productivity Estimation

TFP is widely used in performance and benchmarking analysis. This method is categorized in two main groups that are price index and quantity index. In the case of agricultural water in the developing countries where price data often absent the quantity index is more appropriate. Among quantity index approached where panel data available, the two main frontier methods could by applied that are data envelopment analysis (DEA) that is a non parametric approached and stochastic frontier analysis (SFA) that is a parametric approached (Coelli *et al*., 2005; See and Coelli, 2014).

SFA originally published by Meeusen and van den Broeck and Aigner *et al*., in 1977 almost simultaneously become prominent in parametric analysis (Carvalho and Marquest 2016). Despite SFA widely used in agricultural productivity study, as the best of authors concerns there is no researches applied SFA method to analyze crop water productivity growth particularly in semi arid area of the developing countries.

We applied a SFA with time varying inefficiency with truncated normal distribution to determined TFP growth and decomposed into two components of technical efficiency change (EFC) and technology change (TEC). An output oriented Malmquist index that suitable with agriculture in the developing countries analysis

(Coelli *et al.*, 2003; Coelli *et al.*, 2005) is used. The specification of transient logarithmic stochastic production model as presented in equation below.

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

Where

Y_{it}	= production of i-th crop at t-year
CWU_{it}	= crop water use of i-th crop at t-year
t	= time in year (1, 2 …16)
β_0, β_1, β_2, β_3, β_4 and β_5	= parameters to be estimated
v_{it}	= random error of i-th crop at t-year
u_{it}	= technical inefficiency of i-th crop at t-year

Technical efficiency change (EFC), technology change (TEC), and TFP growth were calculated as follow(Coelli *et al.*, 2005; Hossain *et al.*, 2012; Arshad *et al.*, 2018) :

Technical efficiency change (EFC) :

$$EF_{it} = \frac{Y_{it}}{\exp\left(X_{it}'\beta + v_{it}\right)} = \exp(-u_{it})$$

$$EFC_t = {}^{EF_{it}}/_{EF_{is}}$$

Technology change (TEC) is a geometric mean of two partial time derivation of given production function:

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

Malmquist total factor productivity growth during the period of s to t that is:

$$TFP_t = EFC_t \times TEC_t$$

The TFP and its decomposition were calculated with FRONTIER 4.1. an open source software that provided by centre for efficiency and productivity analysis (CEPA) of the Queensland University-Australia (Coelli *et al.*, 2005). Furthermore, chain analysis of the growth was carried out with the equation below (Goodridge 2007).

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

Where I = Index, X = value, t = current time, t-1 = previous time

Results and Discussion

Climate and Non climate data

Climate data that complete only Kupang municipal and Kupang districts that have a climate station, others district only had monthly rainfall and air temperature provided by rainfall station. Taking into consideration the similarity in climate, topography, and vegetation, it was assumed that the missing data of others districts was similarwith Kupang. The lack of complete data for FAO-PM method frequently happened in the developing countries (Moeletsi *et al*., 2013). Therefore, the use of climate data from nearby station to fill the missing data is recommended (Allen *et al*., 2006; Sentelhas *et al*., 2010).

In terms of climate homogeneity data, RAPS test showed that Kupang climate station ($10^0 08^{'} 19^{''}$SL; $123^0 40^{'} 02^{''}$ EL/ 19 m msl) for Kupang district and Kupang municipal, Soe rain observation post (742 m msl) for TTS district, Kefamenanu rain observation post (381 m msl) for TTU district, and Atambua rain observation post (53 m msl) for Belu district were homogeny (RAPS value < RAPS table of 95% level of confidence). During 2000-2015, in Kupang Municipal and Kupang district mean monthly rainfall, air temperature, maximum air temperature, minimum air temperature, relative humidity, and wind speed at 2 m were 131 mm, 27^0C, 32^0C ,

23^0C , 76%, and 6 knot, respectively. Mean monthly rainfall of TTS district, TTU District and Belu district were 182 mm, 108 mm, and 143 mm, respectively.

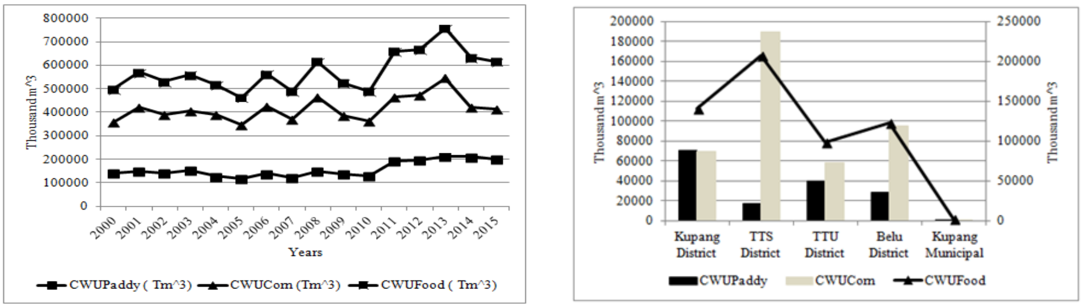
With regard to non climate data, the missing value analysis and outlier analysis were conducted. The result showed that the panel data had a normal distribution at 95 level of confidence as indicated by Shapiro-Wilk test values that exceed 0.05. The average of paddy harvested area (PHA), corn harvested area (CHA), rice production (RPR) and corn kernel production (CPR) for Kupang districts were 15,753 ha/year, 22,532 ha/year, 30,983 ton/year, and 54,581 ton/year respectively. The average PHA, CHA, RPR and CPR for TTS district were 3,563 ha/year, 59,634 ha/year, 7,454 ton/year, and 144,593 ton/year respectively. The average PHA, CHA, RPR and CPR for TTU districts were 9,187 ha/year, 20,864 ha/year, 16,098 ton/year, and 49,412 ton/year respectively. The average values for Belu district were 6,140 ha/year, 31,241 ha/year, 12,588 ton/year, and 71,892 ton/year respectively. The average values for Kupang municipal were 244 ha/year, 455 ha/year, 520 ton/year, and 1,052 ton/year respectively.

Potential Evapotranspiration (ETo)

The first step in WP estimation was to estimate potential evapotranspiration (ETo) and effective rainfall (EFRF). The FAO-PM method which is a standard method was used to acquire ETo. Pandey *et al*. (2016), emphasize that evapotranspiration is an integrated process involving transpiration and evaporation that mostly effected by climate variables, crop characteristics, management practices and environmental merit. The authors furthermore stress that ETo is essential in agricultural water management. The result of the FAO-PM method showed that the averaging ETo during 2000-2015 was 5.228 mm/day with the range of 4.300 mm/day in Ferbruari to 6.388 mm/day in September. Hereinafter, the effective rainfall was 72 mm/month with the range from 3 mm/month in August to 145 mm/month in February.

Crop Water Use (CWU)

The second step was to estimate the crop water use (CWU), the results is presented in Figure1a and 1b. During 2000-2015 showed that CWU was fluctuated among years and districts. Mean averaging CWU_{Paddy}, CWU_{Corn} and CWU_{food} were 157,164 Tm^3/ year, 414,845 Tm^3/year, and 572,009 Tm^3/year respectively. The minimum volume of water use for main food production happened in 2005 and the maximum was in 2013. With regard to the districts, TTS districts used more water compared to others districts and Kupang municipal used the least. Furthermore, TTS districts used much more water in corn production while Kupang district used balanced proportion of water for corn and rice production. Interesting to note that water use for rice and corn production in West Timor were similar with ones that used in India that is provided by Amarasinghe *et al.*, (2007) and with Bangladesh that provided by Amarasinghe *et al.*, (2014). Estimated CWU_{Paddy} of West Timor (4,505 m^3/ha) was higher than India (3,962 m^3/ha) but lower than Bangladesh (4,995 m^3/ha). The estimated CWU_{Corn} of West Timor (3,079 m^3/ha) was exceed both India (2,264 m^3/ha) and Bangladesh (1,430 m^3/ha).



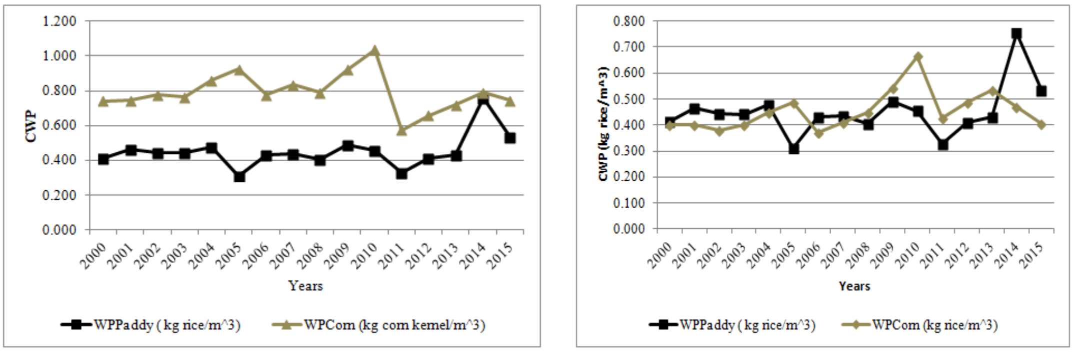
a). Yearly bases b). Districts bases

Fig 1 Main food crop water use (CWU) of West Timor

Gambar terlalu kecil sehingga tidak terbaca

Crop Water Productivity (CWP)

During the last 16 years, paddy water productivity (WP_{Paddy}) in terms of rice (kg) per a volume of CWU_{Paddy} and corn water productivity (WP_{Corn}) in terms of corn kernel (kg) per a volume of CWU_{Corn} as presented in Figure 2a showed a fluctuated trend. In average, WP_{Paddy} was 0.452 ± 0.098 with the range of 0.312 to 0.755 and mean WP_{Corn} was 0.791 ± 0.109 with the range of 0.574 to 1.035. WP_{Paddy} was more fluctuating compared to WP_{Corn} indicated by higher value of the coefficient of variance (cv) that have a value of 21.567% for WP_{Paddy} and 13.781% of WP_{Corn}. These results pointed out that paddy use more water to produce rice compared to the use of water to produce corn kernel. Furthermore, the higher variance in WP_{Paddy} indicated that paddy cultivation in semi arid area more vulnerable than corn. Drought tolerance of corn greater than of paddy, it has been proved that the decision by the majority of farmers in West Timor to cultivate corn was a right and sustainable decision.



a) Paddy and corn kernel b) Paddy and corn equivalent rice

Fig 2 Average main food water productivity

It is interesting to note that the WP_{Paddy} and WP_{Corn} value were in range with global range. The global range of WP_{Paddy} was 0.100 – 2.040 kg/m^3. The lower was experienced in sub-Sahara Africa (Cai and Resegrant 2003) and the upper value was experienced in Indus and Ganggas Basin (Cai *et al*., 2010). The global range of WP_{Corn} was 0.030 – 7.160 kg/m^3. The lower value was based on the experiment in Florida that conducted without irrigation and fertilizer (Nangia *et al*., 2005) and the upper value was based on the experiment in Nebraska with pivot irrigation (Irmak 2015). These results furthermore provided ample opportunity regarding the improvement of WP_{Paddy} and WP_{Corn} in West Timor.

In order to aggregated the WP_{Corn} value to equivalent with WP_{Paddy} , we conversed WP_{Corn} with the initial unit of corn kernel (kg) per volume of CWU to the unit of rice (kg) per volume of CWU. The result as depicted in Figure 2b, showed that mean annually WP_{corn} was 0.455 ± 0.076 rice (kg)/ m^3 with the range of 0.372 – 0.665 rice (kg)/m^3. Moreover, WP_{Food} that composed by the sum rice production and adjusted corn kernel production which divided by CWU_{Food} (accumulation of CWU_{Paddy} and CWU_{Corn}) was 0.454 ± 0.064 rice (kg)/ m^3 with cv of 14.061%. In terms of the variation, WP_{Paddy} was more fluctuated compared to WP_{Corn} and WP_{Food}. The aggregated CWP and WP_{Food} were presented in Figure 3.

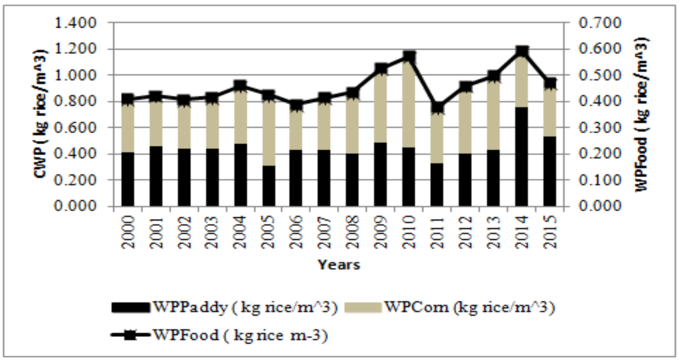


Fig 3 Main food water productivity of West Timor During 2000 - 2015

In terms of main crops water productivity of the districts in West Timor during the last 16 years as depicted in Figure 4, it disclosedthat staple food water productivity was diverse among the districts. WP_{Paddy} was in range of 0.432 to 0.489 rice (kg)/m^3 in which the lowest value and the highest value were in Kupang district and Kupang municipal respectively. WP_{Corn} was in range of 0.429 rice (kg)/m^3 of Belu districts to 0.506 rice (kg)/m^3 of TTU districts. The WP_{Food} had the lowest value of 0.441 rice (kg)/m^3 in Belu districts and the highest value of 0.472 rice (kg)/m^3 in Kupang municipal. As might be expected, the variation of main crops water productivity is mostly effected by the differences of surrounding environment condition where crops are cultivated (Toung and Bouman 2003).

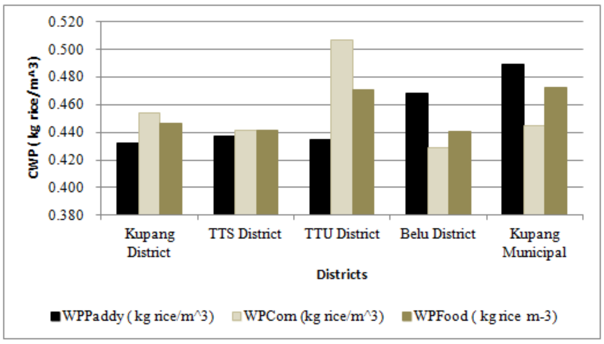


Fig4 Main crop water productivity of each districts

Crop Water Total Factor Productivity Growth

The Maximum Likelihood Estimation (MLE) of the Translog production function parameters under time variant effect and truncated normal distribution was presented in Table 1. The parameter of intercept (β_0) was significant in corn and main food productions. The parameter of water (β_1) was significant for paddy, corn and prime food productions. The parameters of water squared (β_2) was significant in corn production. The interactions of water over years (β_3), and the parameter of time (β_4) were not significant. The parameter of time squared (β_5) was significant for paddy production.

Table 1. Stochastic frontier production function for main food production in West Timor

Production function Parameters		Coefficient	t-ratio
Rice Production			
Intercept	β_0	-1.80E+00	-7.76E-01
Water	β_1	1.17E+00	3.95E+00**
Water^2	β_2	-1.25E-02	-6.63E-01
Water * Time	β_3	-4.81E-04	-1.84E-01
Time	β_4	-3.78E-02	-8.29E-01
Time^2	β_5	5.68E-03	.97E+00**
Sigma^2	σ^2	2.55E-02	6.27E+00**
Gamma	γ	2.94E-05	8.09E-02
Mu	μ	-1.73E-03	-2.41E-02
Eta	η	4.28E-03	1.43E-02
Corn Production (Equivalent rice)			

Intercept	β_0	-5.55E+00	-5.65E+00**
Water	β_1	1.53E+00	1.22E+01**
Water^2	β_2	-3.07E-02	-3.78E+00**
Water * year	β_3	-2.42E-03	-9.01E-01
Time	β_4	9.46E-02	1.70E+00
Time^2	β_5	-3.55E-03	-1.62E+00
Sigma^2	σ^2	3.82E-02	1.06E+01**
Gamma	γ	1.08E-01	8.87E-01
Mu	μ	1.28E-01	9.43E-01
Eta	η	-1.71E-01	-4.31E-01
Main food Production			
Intercept	β_0	-3.53E+00	-2.66E+00**
Water	β_1	1.30E+00	8.12E+00**
Water^2	β_2	-1.66E-02	-1.70E+00
Water * Time	β_3	-3.74E-03	-1.64E+00
Time	β_4	7.17E-02	1.66E+00
Time^2	β_5	1.18E-03	6.57E-01
Sigma^2	σ^2	2.01E-06	6.11E+00**
Gamma	γ	2.01E-06	2.15E-02
Mu	μ	-4.25E-04	-2.93E-03
Eta	η	-6.65E-03	-2.85E-02

Note: ** = significant at 5% level ($p<0.05$)

The coefficient of water was positive and significant for all models indicated that the water was the prominent factor in rice, corn, and main food production. Remarkably the result support the notion that water is the prominent input and limiting factor for food production in semi arid tropic that dominated by rainfed agricultural (Rockström *et al.*, 2003). The sigma squared (σ^2) parameter indicated total variance from random error and from inefficiency effect was significant for all production functions. Parameter gamma (γ) that explained the ratio of technical efficiency effect from total variance was not significant for all production functions. This implied that rice production, corn production, and main food production were have lower technical efficiency effect, then most of the variance ware due to random effect or external factors. This result to some degree contradict with the study of rice productivity in Bangladesh that incorporating more variables exclude water in which have the significant higher technical efficiency effect compared to random effect (Coelli *et al*., 2003; Hossain *et al*., 2012).

The parameter of mu (μ) for all models were not equal to zero and insignificant indicated that the efficiencies were not a half normal distribution. Furthermore, the technical inefficiency effect of the models was diver over years (η ǂ 0) but not significant, the negative value of η exhibited that technical efficiency was decreasing over years. The small negative coefficient of time expressed the downfall of technology change and the positive coefficient indicated the rise of technology change. The positive coefficient of time squared indicated that the change is linier for rice production but non linier in both corn and main food productions. However changes were not significant (Coelli *et al*., 2003). Moreover, the negative intercept value indicated the decreasing of technology change over time that not significant for rice production but significant for both corn and main food production (Hossain *et al*., 2012).

Rice Water TFP Growth

Rice water total factor productivity growth per annum is presented in Table 2 showed that there was a steady growth of efficiency change (EFC) while there were an increasing change of technology (TEC) and total factor productivity (TFP) over years during 2000-2015. Mean annually of EFC, TEC and TFC were 1.000, 1.003, and 1.003, respectively. The lowest growth of TFP was during 2000-2001 and the highest growth was during 2014-2015. The growth variance was low indicated by 2.527% of coefficient of variance (cv). It is important to note that the farmers in West

Timor was efficient in using water for rice production given the technology frontier The WP_{Paddy} TFP growth was mostly effected by TEC.

Table 2. Annually WP_{Paddy}TFP Growth of West Timor during 2000-2015

Years	EFC	TEC	TFP
2000-2001	1.000	0.963	0.963
2001-2002	1.000	0.968	0.968
2002-2003	1.000	0.974	0.974
2003-2004	1.000	0.980	0.980
2004-2005	1.000	0.986	0.986
2005-2006	1.000	0.991	0.991
2006-2007	1.000	0.997	0.997
2007-2008	1.000	1.003	1.003
2008-2009	1.000	1.008	1.008
2009-2010	1.000	1.014	1.014
2010-2011	1.000	1.020	1.020
2011-2012	1.000	1.025	1.025
2012-2013	1.000	1.031	1.031
2013-2014	1.000	1.036	1.036
2014-2015	1.000	1.042	1.042

The changing of rice water TFP growth during 2000-2015 as depicted in Figure 5 indicated that there were a persistent of EFC and a constant growth of TFC and TFP. There were no change in EFC and an 8.219% increasing of TEC and TFC. The long adaptation with semi arid climate proved that farmers are efficient in using water for rice production in the particularly level of technology, it was contradicted with the perception that traditional farmers tend to inefficient in using water for crop production. Furthermore, as might be expected in order to boost rice water productivity was through the improvement in rice production technology while maintain the level of efficiency.

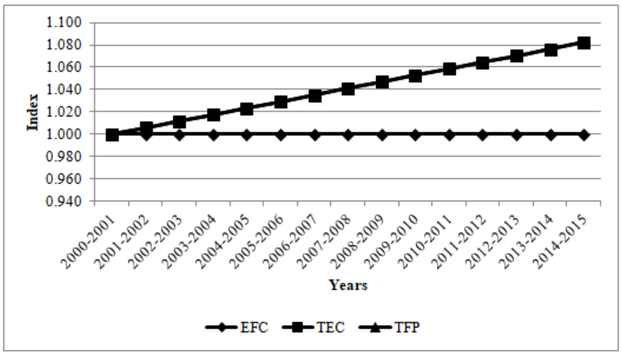


Fig5 Chain indices of WPPaddy TFP growth

In terms of WP_{Paddy} TFP growth in each district as depicted in Figure 6 indicated that there was a similar level of EFC across the districts, the change of TFP due to the change of TEC that fluctuated across the districts. The lowest value of TEC was in Kupang districts while the highest value was in Kupang municipal. Despite Kupang district was the forefront of rice production and Kupang municipal was the lowest rice production in West Timor, farmers of the municipal showed that they use water more efficient and effective in rice production.

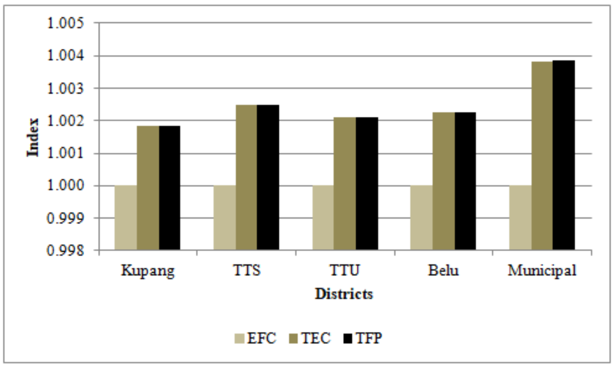


Fig6 WP_{Paddy} TFP growth of each districts

Corn Water TFP Growth

With regard to corn water TFP growth in terms of rice equivalent per cubic of CWU in period 2000-2015 as presented in Table 3 showed that there was a diminished of EFC, TEC and TFP over time. Mean EFC, TEC, and TFP were 0.992, 1.022, and 1.014 respectively. Moreover, the range of WP_{Corn} EFC, TEC, and TFP were 0.980 - 0.998, 0.997 - 1.047, and 0.997 - 1.043 respectively. The lowest growth of EFC, TEC, and TFP were in 2014-2015 while the highest growth of EFC was in 2001-2002 and the higher growth either TEC or TFP were in 2000-2001. The variance of EFC lowers than the variance of TEC and TFP that account for 0.576%, 1.558%, and 2.106% respectively. Worth noting, corn that cultivated by most of the farmers and more tolerance to drought compared to paddy in average showed better growth of TEC and TFP. Relatively farmers were efficient in use water for corn production. There is however, not only due to the great dependency on rainfall was that uncertain in semi arid region but also have the limited production input predisposed the efficiency lower compared to WP_{Paddy} EFC. Therefore, there was a considerable room for 1.820% improvement of corn water EFC.

Table 3. Corn water TFP growth during 2000-2015

Years	EFC	TEC	TFP
2000-2001	0.997	1.047	1.043
2001-2002	0.998	1.043	1.041
2002-2003	0.997	1.040	1.037
2003-2004	0.997	1.036	1.033
2004-2005	0.996	1.033	1.029
2005-2006	0.996	1.029	1.025
2006-2007	0.995	1.026	1.020
2007-2008	0.994	1.022	1.015
2008-2009	0.993	1.018	1.011
2009-2010	0.991	1.015	1.006
2010-2011	0.990	1.012	1.001
2011-2012	0.988	1.008	0.995
2012-2013	0.985	1.004	0.989
2013-2014	0.983	1.001	0.983
2014-2015	0.980	0.997	0.977

Chain indices of WP_{Corn} TFP growth as depict in Figure 7 showed that there were a decreasing of EFC, TEC and TFP. The magnitude of the decreasing denoted the decreasing of TFP and TEC more intensive than the EFC. During the last 16 years there were a downfall of 1.712%, 4.738%, and 6.370% for EFC, TEC, and TFP respectively. The downfall of corn water TFP growth and its components figured out that the corn farmers' capacity and technology extent were unable to fully cope with the changing environment. The fact that TEC was the driven factor of TFP growth thereafter the development of corn production technology to deal with is envisaged.

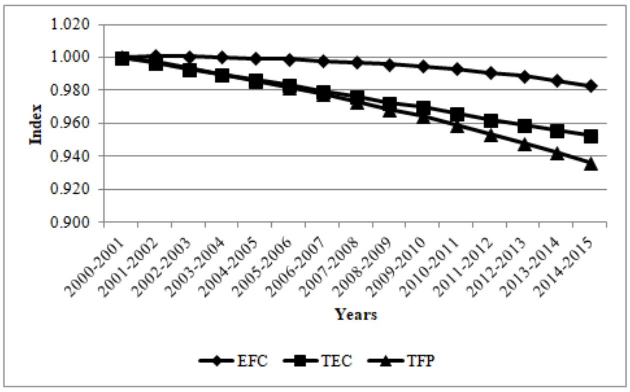


Fig 7 The chain indices of corn water TFP growth

Taking into consideration the districts performance over WP_{Corn} TFP growth as presented in Figure 8, TFP and its component of EFC and TEC were varied. The lowest EFC of 0.988 was in Belu district and the highest of 0.994 was in TTU district. TTS district had the lowest TEC index of 1.018 and Kupang municipal had the highest (1.030). The lowest index of TFP was in Belu district (1.008) and the highest index in Kupang municipal of 1.021. Similar with rice water TFP growth, Kupang municipal that have a lower production and lower CWU_{Corn} posesed the hight TFP growth.

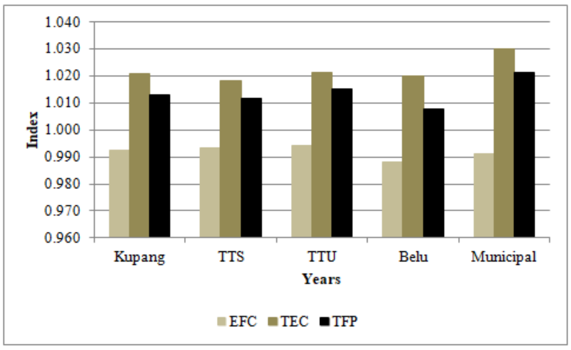


Fig 8 Districts performance of corn water productivity growth

Staple Food Water TFP Growth

Regarding staple food water TFP growth during 2000-2015 as presented in Table 4 showed the resembling pattern with rice water TFP growth. During the period there was no change in EFC and there were an increasing of TEC and TFP. Mean annually EFC, TEC and TFP were 1.000, 1.015, and 1.015 respectively. This result pointed out that, farmers in West Timor were relatively very efficient in using water for staple food production. Additionally, the growth of TEC influences the growth of TFP that during the period the mean expansion of both TEC and TFC was 1.482% with the low variance indicated by 0.496% of cv. The range of TEC and TFP was between 1.007 that occur in 2000-2001 and 1.023 that occur in 2014-2015.

Table 4. Staple food water TFP growth

Years	EFC	TEC	TFP
2000-2001	1.000	1.007	1.007
2001-2002	1.000	1.008	1.008
2002-2003	1.000	1.009	1.009
2003-2004	1.000	1.010	1.010
2004-2005	1.000	1.012	1.012
2005-2006	1.000	1.013	1.013
2006-2007	1.000	1.014	1.014
2007-2008	1.000	1.015	1.015
2008-2009	1.000	1.016	1.016
2009-2010	1.000	1.018	1.018

2010-2011	1.000	1.018	1.018
2011-2012	1.000	1.019	1.019
2012-2013	1.000	1.020	1.020
2013-2014	1.000	1.021	1.021
2014-2015	1.000	1.023	1.023

Chain indices of staple food water TFP growth as depicted in Figure 9 indicated that there was a fixed growth of EFC while there was a rising of 1.593% of TEC and TFP. The expansion of TEC that resulting in the expansion of TFP was the indicator of fruitfulness of agriculture water management practice. However, despite the increasing of TFP growth there is still chance to improved $WP_{Food,}$ given the level of EFC was adequate the improvement in production technology leading to raise the yield was envisage. Ali and Talukder (2008) furthermore pointed out that in arid and semi arid climate, water and nutrient shortfall are the main cause and limiting factor for crop yield leading to reduce crop water productivity. Moreover, Brauman *et al.*, (2013) stressed that crop water productivity merely not only depend on climate but on non climate also. It is advisable that the appropriate enhancement of staple food WP by means the development and the diffusion of main food production technology as well as the increasing of farmers' socio-economy capacity.

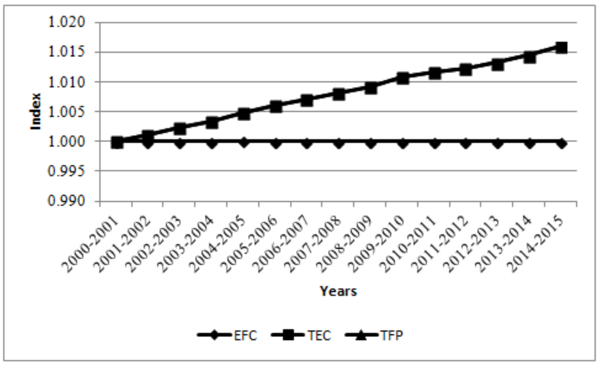


Fig 9 Chain indices of staple food water TFP growth

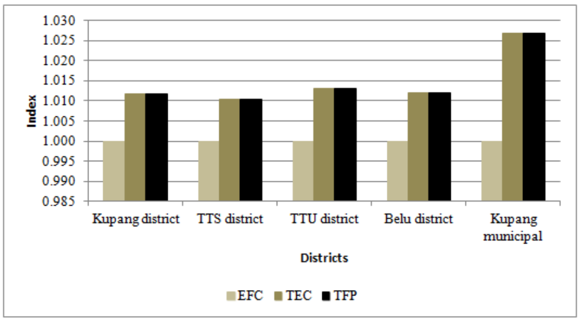


Fig 10 Districts performance of staple food water TFP growth

The district performance in terms of main food water TFP growth as represented in Figure 10 showed that TFP and the components of EFC and TEC relative similar across the districts except for Kupang municipal that had the better TEC and TFP growth. Despite TTS district was sublime in corn production the district possessed the lowest main food TEC and TFP Growth. Kupang municipal as a capital city of the province gravitate to have better access to food input production and has a better socio-economy capacity to managing water to produce staple food.

Implication to Food Security

The proper way to enhancement staple food water TFP growth was by the increase of TEC. The present growth during the last 16 years was 1.5% per annum would be due to firstly, the increase of main food production with the constant of CWU_{Food}, secondly by the constant of main food production with the reduction of CWU_{Food} and thirdly and that was the case in West Timor that by the increase of both main food production and CWU_{Food}. In addition, furthermore the improvement of TFP and the outcome for food security as presented in Table 5 explained that the TEC improvement of 10%, 20%, and 25% would elevate the rice production by 45,701 ton, 87,247 ton, and 108,020 ton, respectively.

Table 5. Main food TFP growth and rice production improvement

Components	EFC	TEC	TFP	Rice (ton)
Annually mean	1.000	1.015	1.015	
Annually change (%)	0.000	1.500	1.500	
A 10% increase	1.000	1.165	1.165	45,701
A 20% increase	1.000	1.315	1.315	87,247
A 25% increase	1.000	1.390	1.390	108,020

Ali and Talukder (2008) suggested that in order to improve CWP demanded the enhancement of water management strategies, cultivar improvement, fertility management, cultural practices and economic consideration. Passioura (2006) furthermore point out that agronomic and cultivar improvements are the main concern in CWP growth, that coupling with enhancement of farm management regarding the provision of better input and the willing to take social and economic risks of crop failure. Kang *et al*., (2017) stressed that the importance of dynamic interconnections among food production- water management-ecosystem in achieving a sustainable CWP improvement.

Conclusion (saran: kesimpulan dipersingkat, dan tanpa nomor)

i. Three types of staple crop water productivity namely WP_{Rice}, WP_{corn}, and WP_{Food} were estimated. Water was the prominent factor in staple food production; however the interaction with years was not significant.

ii. The TFP growth and the components of EFC and TEC indicated that WP_{Rice} and WP_{Food} had experienced no change in EFC and the improvement in both TEC and TFP. WP_{Corn} sustain the downfall of EFC, TEC and TFP respectively. Surprisingly, farmers in West Timor relatively efficient in using water for prime food crops that finding departs from common perspective.

Technology change (TFC) was the driven force of TFP growth. The districts with better access to production input and technology diffusion performs better in food water TFP growth.

iii. The appropriate step in the improvement of staple food water TFP growth was the enhancement of production technology. The increase of TEC inflicted the TFP growth that leading to boost the main food production that outcome would strengthen the food security in the semi arid area.

iv. It is advisable that ways in which TFP growth being improved is by the improvement of production technology with taking into consideration climate and non climate factors that affecting the production of more staple food with proportional volume of water. Moreover, maintaining the balance of food-water-ecosystem dynamic interrelation was the key to sustain the growth.

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Conflict of Interests

The authors furthermore declare that there is no conflict of interests regarding this study.

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Staple food water total factor productivity growth towards food security in West Timor, Indonesia

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ABSTRACT

One of the prominent ways to boost food security in semi arid region like West Timor where water is scarce is by the increasing of food water productivity or to increase food production with less water. This study made a remarkable contribution with taking into consideration food water TFP growth with its components of efficiency change and technology change. This study furthermore focused on the estimation of food water productivity, the estimation of food water TFP growth and the implication to food security. For doing so, 16 years secondary balanced panel data of climate and non climate data were used. We applied FAO Penman-Monteith method in estimating crop water use as the denominator of water productivity subsequently stochastic frontier analysis- Malmquist index in estimating food water TFP growth and its decomposition. The results showed that during 2000-2015, food water productivity in terms of production per crop water use showed a fluctuated trend, with averaging WP_{Paddy}, WP_{Corn} and WP_{Food} which is aggregated of paddy and corn were 0.459 kg rice/m^3, 0.455 kg equivalen rice /m^3 and 0.458 kg rice/m^3, respectively. Averaging TFP growth of WP_{Food} was 1.015 respectively. It is important to note that the TFP growths were mostly influenced by technology growth rather than efficiency growth. The municipal of Kupang had the higher TFP growth compared to other districts. Therefore the improvement in production technology, better access to production input, and enhancing farms management are the key to sustainable food security in West Timor.

Key words : *Stochastic frontier analysis, Technology change, Ccorn, Rice, Water productivity*

Introduction

Nowadays most of developing countries are facing a food security challenge due to the rapid population growth coupling with natural resources degradation and uncertainty in climate change. Those negative effects could demote agricultural production leading to widening the food security gap. Water is the prominent input in agricultural production, it is imperative to boost agricultural water management through improving agricultural water efficiency so the production could be improved with proper amount of water (Rosegrant *et al*., 2009; Brauman *et al*., 2013).

With regard to semi arid region like West Timor which a part of East Nusa Tenggara (NTT) Province of Indonesia, the staple food are paddy (*Oryza sativa* L.) and corn (*Zea mays* L.). Agriculture is main source of living for the population (61%). However, subsistence traditional farming in dry land environment dominating the agriculture practices, only about 10% of farmers doing a commercial farming (Foenay, 2000). Corn cultivation that mostly in dry land areas (*ladang, kebun*) dominated paddy cultivation that mostly planting in wet land areas (*sawah*) that is more intensive compared to corn cultivation.

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In addition, more than a half of farmers experience climate change and natural disaster of drought and high intensity rain, 48.47% of paddy households and 57.51% of corn households (BPS NTT, 2016). Despite there is an increasing of food production WFP (2015) reported that there is a 30% of sub districts in West Timor categorized as vulnerable to food security.

Dealing with the problems mention above it is believed to increase crop yield with the reduction of water use or by using the same amount of water to produce more food. That means the increasing of crop water productivity (CWP) (Kang *et al*., 2017). Molden (1997) presented the first prominent research in water productivity. Water productivity that evolves from previous water use efficiency concept is defined as the marketable crop yield per actual evapotranspiration (ETa) (Zwart and Bastiaanssen, 2004). ETa in large areas with continuous measure facing considerable difficulties furthermore it is suggested to estimate by indirect method using crop water use (CWU). CWU is the volume of water that transpires by crops and evaporates from crop surrounding areas during the growing periods (Amarasinghe *et al*., 2007; Sharma *et al*., 2015).

There are considerable researches regarding CWP in the developing countries, however very little discussion regarding temporal and spatial growth. The works of Alauddin and Sharma (2013) and Alauddin *et al*., (2014) by using panel data furthermore provide the rice water productivity growth of 21 Bangladesh districts over 37 years. Mean rice water productivity in Bangladesh is 0.361 kg/m^3 of CWU with the average annual growth of 2.14%.

However, there is still not clear understanding regarding crop water total factor productivity growth that constructed by efficiency change and technology change. Likewise concerning crop water productivity growth that related to food security in semi arid areas of developing countries where most of the population depending heavily on traditional agriculture. This study is intended to fill the gap furthermore to contribute to the water productivity and food security researches.

In terms of productivity growth analysis nowadays a total factor productivity (TFP) growth is more robust compared to traditional productivity analysis. Traditional productivity analysis is limited to study the impact of technology growth under the assumption that the production unit operate in efficient form. TFP analysis on the other hand provides more robust result due to the TFP growth constructed not only by technology change (TEC) but also by efficiency change (EFC). The positive growth of TFP is gained by an increasing of production frontier or by the increasing of production efficiency that catching up with given production technology. Additionally, Malmquist Index is widely used to specify the TFP growth and its decomposition to TEC and EFC (Coelli *et al*., 2005; Chen *et al*., 2017).

Malmquist index furthermore could be determined by both non parametric approached and parametric approached. The stochastic frontier analysis (SFA) is classified in the parametric approached with the advantages include the results is minimal from bias because the use of parametric data, the efficiency component is extracted from random variable, it's using functional forms that flexible in define systems under study, and that enable to conduct statistical test (Coelli *et al*., 2005).

This study furthermore focused on the estimation CWU leading to the estimation of food water productivity (WP_{Food}) that was the aggregated of paddy and corn water productivity. Subsequently this study had estimated WP_{Food} TFP growth as well as the implications towards food security.

Materials and Methods

The Study Area

This study was conducted at West Timor that is located at 123^0 27′ 40" – 125^0 11′ 59" East Longitude and 08^0 56′ 17" – 10^0 21′ 56" South Latitude. The region has a municipal (Kupang) that the capital city of The East Nusa Tenggara (NTT) Province and four districts namely Kupang district, South Central Timor (TTS) district, North Central Timor district (TTU) and Belu district.

Data Sources and Preparations

This study used climate and non climate balance panel data of 2000 to 2105. The climate data included monthly rainfall, monthly average, minimum and maximum air temperature; monthly wind speed, monthly average humidity. The Rescaled adjusted partial sums (RAPS) homogeneity test was applied, the test more suitable for developing countries climate stations. The non climate data were crop harvested data, crop production data, and crop price data that provided by NTT Province bureau of statistics (BPS NTT). Additionally, average crop planting time provided by (Runtunuwu *et al*., 2013) and crop coefficient (Kc) that was suitable with Indonesian condition that provided by Indonesian water resources bureau. In order to get the balance panel data with a normal distribution, then the missing value analysis with Lagrange interpolation, outlier analysis and a Shapiro-Wilk test were carried out.

Food Water Productivity Estimation

There were three steps in conducted the food WP estimation. Firstly, the climate data was utilized to estimate the potential evapotranspiration (ETo) based on FAO Penman-Monteith (FAO-PM) method with the help of FAO-ETo calculator (Raes 2012). The effective rainfall furthermore was estimated by 75% probability as suggested by (Amarasinghe *et al*., 2005; Amarasinghe *et al*., 2007; Alauddin and Sharma 2013; Alauddin *et al*., 2014). Secondly to interpret the CWU based on the method by (Amarasinghe *et al*., 2007; Alauddin and Sharma 2013; Alauddin *et al*., 2014; Amarasinghe *et al*., 2014, Sharma *et al*., 2015) with some adjustment to meet with available data and unlike previous method that put forward irrigation type as bases, in this study we set the crops as the bases. Thirdly, crops water productivity (CWP) was estimated based on the equations below.

$$CWP = \frac{\text{Crop Production (kg)}}{\text{CWU (m}^3\text{)}}$$

In order to have a staple food production as a single output, we were conversed corn production into equivalent rice production by using local price comparison, as formulated below:

$$\text{Rice equivalent}_t = \frac{\text{Corn price}_t}{\text{Rice price}_t}\ (\text{Corn production}_t)$$

$$WP_{Food',\,t} = (\text{Rice production}_t + \text{Rice equivalent}_t)/CWU_{Food,t}$$

Total Factor Productivity Estimation

We applied a stochastic frontier analysis (SFA) with an output oriented Malmquist index that suitable with the agriculture productivity analysis in the developing countries to determined TFP growth and decomposed into technical efficiency change (EFC) and technology change (TEC). It is assumed that the efficiency effect were truncated normal distribution and time varying (Coelli *et al*., 2003; Coelli *et al*., 2005).

The specification of transient logarithmic stochastic production model as presented in equation below.

$$\ln Y_{it} = \beta_0 + \beta_1 \ln (CWU_{it}) + 0.5\, \beta_2 \ln (CWU^2_{it}) + \beta_3 \ln (CWU_{it} \times t) + \beta_4 \ln (t) + 0.5\, \beta_5 \ln (t^2) + V_{it} - U_{it}$$

Where

Y_{it} = production of i-th district at t-year

CWU_{it} = crop water use of i-th district at t-year

t = time in year (1, 2 …16)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ and β_5 = parameters to be estimated

v_{it} = random error of i-th district at t-year

u_{it} = technical inefficiency of i-th district at t-year

Technical efficiency change (EFC), technology change (TEC), and TFP growth were calculated as follow (Coelli *et al*., 2005; Hossain *et al*., 2012; Arshad *et al*., 2018) :

$$EF_{it} = \frac{Y_{it}}{\exp\left(X'_{it}\beta + v_{it}\right)} = \exp(-u_{it})$$

$$EFC_t = \frac{EF_{it}}{EF_{is}}$$

Technology change (TEC) is a geometric mean of two partial time derivation of given production function:

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

Malmquist total factor productivity growth during the period of s to t that is:

$$TFP_t = EFC_t \times TEC_t$$

The TFP and its decomposition were calculated with FRONTIER 4.1. the open source software that provided by centre for efficiency and productivity analysis (CEPA) of the Queensland University-Australia (Coelli *et al*., 2005). Furthermore, chain analysis of the growth was carried out with the equation below (Goodridge, 2007).

$$I_t = \left({}^{X_t}/_{X_s}\right) I_s$$

Where I = Index, X = value, t = current time, t-1 = previous time

Results and Discussion

Potential Evapotranspiration (ETo)

The first step in WP estimation was to estimate potential evapotranspiration (ETo) and effective rainfall (EFRF). The FAO-PM method which is a standard method was used to acquire ETo. Pandey *et al.* (2016), emphasize that evapotranspiration is an integrated process involving transpiration and evaporation that mostly effected by climate variables, crop characteristics, management practices and environmental merit. The result of the FAO-PM method showed that the averaging ETo during 2000-2015 was 5.228 mm/day with the range of 4.300 mm/day in Ferbruari to 6.388 mm/day in September. Hereinafter, the average effective rainfall was 72 mm/month with the range from 3 mm/month in August to 145 mm/month in February.

Staple Food Water Use (CWU)

The second step was to estimate the crop water use (CWU), the result was presented in Figure 1. During 2000-2015 CWU was fluctuated among years and districts. The mean of CWU_{Paddy}, CWU_{Corn} and CWU_{food} were 157,164 Tm^3/ year, 414,845 Tm^3/year, and 572,009 Tm^3/year respectively. The minimum volume of water use for main food production happened in 2005 and the maximum was in 2013. With regard to the districts, TTS districts used more water compared to others districts and Kupang municipal used the least.

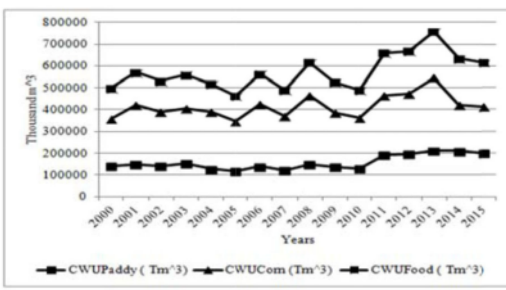

Fig. 1. Staple food crop water use of West Timor - yearly bases

Staple Food Water Productivity (CWP)

During the last 16 years, paddy water productivity (WP_{Paddy}) in terms of rice (kg) per a volume of CWU_{Paddy} and corn water productivity (WP_{Corn}) in terms of corn kernel (kg) per a volume of CWU_{Corn} showed a fluctuated trend. In the average, WP_{Paddy} was 0.452 ± 0.098 kg/m^3 with the range of 0.312 to 0.755 kg/m^3 and the average of WP_{Corn} was 0.791 ± 0.109 kg/m^3 with the range of 0.574 to 1.035 kg/m^3.

It is interesting to note that the WP_{Paddy} and WP_{Corn} values were in range with global reports. The global range of WP_{Paddy} was 0.100 – 2.040 kg/m^3. The lower value was experienced in sub-Sahara Africa (Cai and Resegrant, 2003) and the upper value was experienced in Indus and Ganggas Basin (Cai *et al.*, 2010). The global range of WP_{Corn} was 0.030 – 7.160 kg/m^3. The lower value was based on the experiment in Florida that conducted without irrigation and fertilizer (Nangia *et al.*, 2008) and the upper value was based on the experiment in Nebraska with pivot irrigation (Irmak, 2015). These results furthermore provided ample opportunity to improve WP_{Paddy} and WP_{Corn} in the West Timor.

In order to aggregate the WP_{Corn} value to equivalent with WP_{Paddy}, we converse WP_{Corn} of corn kernel (kg) per volume of CWU to the unit of rice (kg) per volume of CWU. Mean annually WP_{corn} was 0.455 ± 0.076 rice (kg)/ m^3 with the range of 0.372 – 0.665 rice (kg)/m^3. Therefore, WP_{Food} that composed by the sum of rice production and adjusted corn kernel production which divided by CWU_{Food} (accumulation of CWU_{Paddy} and CWU_{Corn}) was 0.454 ± 0.064 rice (kg)/ m^3. The aggregated CWP and WP_{Food} were presented in Figure 2.

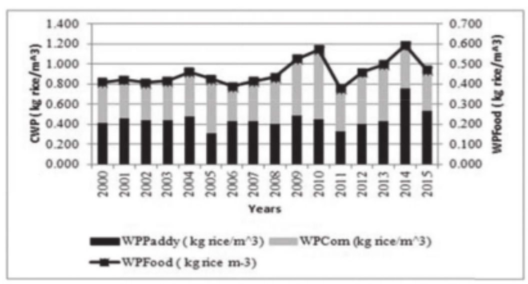

Fig. 2. Staple food water productivity of West Timor During 2000 - 2015

Staple Food Water Total Factor Productivity Growth

The Maximum Likelihood Estimation (MLE) of the Translog production function parameters under truncated normal distribution and time variant efficiency effect was presented in Table 1. The coefficient of water was positive and significant indicated that the water was the prominent factor in the staple food production. Remarkably the result support the notion that water is the prominent input and limiting factor for food production in semi arid tropic that dominated by rain fed agricultural (Rockström *et al*., 2003). However, the time variables and its interaction with water were not significant.

Table 1. Stochastic frontier production function for staple food production in the West Timor

Parameters		Production function Coefficient	t-ratio
Staple food Production			
Intercept	β_0	-3.53E+00	-2.66E+00**
Water	β_1	1.30E+00	8.12E+00**
Water²	β_2	-1.66E-02	-1.70E+00
Water * Time	β_3	-3.74E-03	-1.64E+00
Time	β_4	7.17E-02	1.66E+00
Time²	β_5	1.18E-03	6.57E-01
Sigma²	σ^2	2.01E-06	6.11E+00**
Gamma	γ	2.01E-06	2.15E-02
Mu	μ	-4.25E-04	-2.93E-03
Eta	η	-6.65E-03	-2.85E-02

Note: ** = significant at 5% level ($p<0.05$)

The sigma squared (σ^2) parameter indicated total variance from random error and from inefficiency effect was significant. Parameter gamma (γ) that explained the ratio of technical efficiency effect from total variance was not significant. This implied that the staple food production were have lower technical efficiency effect, then most of the variance ware due to random effect or external factors (Coelli *et al.*, 2003; Hossain *et al.*, 2012).

The parameter of mu (μ) was not equal to zero and insignificant indicated that the efficiencies were not significant had a truncated normal distribution. Furthermore, the technical inefficiency effect of the models was diver over years ($\eta \neq 0$) but not significant, the negative value of η exhibited that technical efficiency was decreasing over years. The small positive coefficient of time expressed the rise of technology change. The positive coefficient of time squared indicated that the change was non linier and not significant (Coelli *et al*., 2003).

Staple Food Water Total Factor Productivity Growth

The staple food water TFP growth during 2000-2015 that presented in Table 2 showed that there was no change in EFC and there were an increasing of TEC and TFP. Mean annually EFC, TEC and TFP were 1.000, 1.015, and 1.015 respectively.

Table 2. Staple food water TFP growth

Years	EFC	TEC	TFP
2000-2001	1.000	1.007	1.007
2001-2002	1.000	1.008	1.008
2002-2003	1.000	1.009	1.009
2003-2004	1.000	1.010	1.010
2004-2005	1.000	1.012	1.012
2005-2006	1.000	1.013	1.013
2006-2007	1.000	1.014	1.014
2007-2008	1.000	1.015	1.015
2008-2009	1.000	1.016	1.016
2009-2010	1.000	1.018	1.018
2010-2011	1.000	1.018	1.018
2011-2012	1.000	1.019	1.019
2012-2013	1.000	1.020	1.020
2013-2014	1.000	1.021	1.021
2014-2015	1.000	1.023	1.023

This result pointed out that, farmers in West Timor were relatively efficient in using water for staple food production. Additionally, the growth of TEC influences the growth of TFP. The range of TEC and TFP was between 1.007 that occur in 2000-2001 and 1.023 that occur in 2014-2015.

Chain indices of staple food water TFP growth as depicted in Figure 3 indicated that there was a fixed growth of EFC while there was an increasing of TEC and TFP by 1.593% respectively. The expansion of TEC that resulting in the expansion of TFP was due to the fruitfulness of agriculture production technology practice. However, despite the increasing of TFP growth there is still chance to improved $WP_{Food,}$ given the level of EFC was adequate the improvement in production technology leading to raise the yield was envisage.

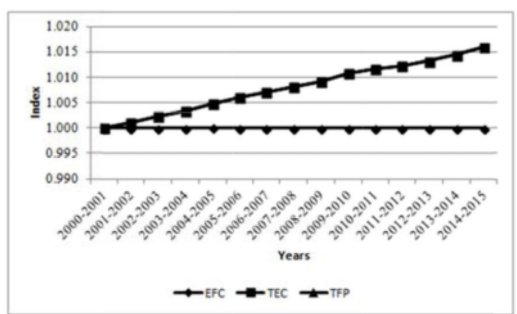

Fig 3 Chain indices of staple food water TFP growth

Ali and Talukder (2008) pointed out that in arid and semi arid climate, water and nutrient shortfall are the main cause and limiting factor for crop yield leading to reduced crop water productivity. Moreover, Brauman *et al.*, (2013) stressed that crop water productivity merely not only depend on climate but on non climate also. It is advisable that the appropriate enhancement of staple food WP by means the development and the diffusion of main food production technology as well as the increasing of farmers' socio-economy capacity.

In terms of the districts performance as depicted in Figure 4 showed that staple food water TFP growth and the components of EFC and TEC were relatively similar across the districts except for Kupang municipal that had the better TEC and TFP growth. Kupang municipal as a capital city of the province gravitate to have better access to agriculture input production and has a better socio-economy capacity to managing water for staple food.

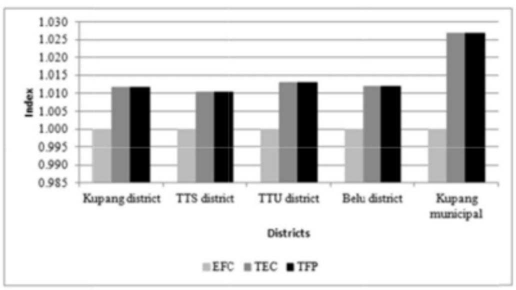

Fig 4. Districts performance of staple food water TFP growth

Implication to Food Security

The proper way to enhancement of staple food water TFP growth was by the increase of TEC. The present growth during the last 16 years was 1.5% through the increased of main food production and CWU_{Food}. Furthermore, the simulation of TFP improvement and the outcome towards food security was presented in Table 3. The simulation resulted that the TEC improvement of 10%, 20%, and 25% while maintaining the growth of EFC would elevate the rice production by 45,701 ton, 87,247 ton, and 108,020 ton, respectively.

Ali and Talukder (2008) point out that the improvement of CWP demanded the enhancement of water management strategies, cultivar improvement, fertility management, cultural practices and economic consideration. Passioura (2006) furthermore highlight that agronomic and cultivar improvements are the main concern in CWP growth, that have to include with the enhancement of farm management regarding the provision of better input and the willingness of farmers to take social and economic risks of crop failure.

Conclusion

Staple food water productivity value of West Timor region during 2000-2015 was in range with what reported worldwide. Water was the prominent factor in staple food production; however the interaction with years was not significant. Surprisingly, farmers in West Timor relatively efficient in using water for prime food production. WP_{Food} had experienced no change in EFC and the improvement in both TEC and TFP. Technology change (TEC) was the driven force of TFP growth. The districts with better access to production input and technology perform better in staple food water TFP growth. Therefore, the appropriate step in the improvement of staple food water TFP growth was the enhancement of production technology (TEC). The increase of TEC inflicted the TFP growth that leading to boost the staple food production that outcome would strengthen the food security in the semi arid area.

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Table 3. Main food TFP growth and rice production improvement

Components	EFC	TEC	TFP	Rice (ton)
Mean indices	1.000	1.015	1.015	
Current change (%)	0.000	1.500	1.500	
10% increase	1.000	1.165	1.165	45,701
20% increase	1.000	1.315	1.315	87,247
25% increase	1.000	1.390	1.390	108,020

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