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Corn Water Productivity growth using Stochastic Frontier Analysis Malmquist Index (A case of West Timor – Indonesia)

Penulis :

Jonathan E. Koehuan, Bambang Suharto, Gunomo Djoyowasito and Liliya D. Susanawati

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Email: icobas@uin-malang.ac.id
Telepon : 0341-558933; Faks : 0341-558933
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Corn Water Productivity G~~g~~rowth of West Timor, Indonesia

Abstract. Corn is one of the most popular crops worldwide, including~~es~~ for ~~the~~ West Timor farmers. However, ~~there is a~~ very limited reports on corn water productivity (WP$_{Corn}$~~–~~) growth exist. This research would make a remarkable contribution to fill this~~e~~ gap. This study aims to estimate ~~corn water productivity (~~WP$_{Corn}$~~)~~ of West Timor ~~subsequently~~ to subsequently determine its total factor productivity (TFP) growth during 2000–~~-~~2015. ~~-~~To do~~ing~~ so, we used 16 years of balanced panel data on~~f~~ climate and the crop ~~data~~. WP$_{Corn}$ was estimated based on corn water use (CWU$_{Corn}$). Then, SFA-MI was applied to determine TFP growth. The results showed that mean WP$_{Corn}$ in this region was 0.782 kg/m^3 water use, the highest ~~was~~ being 1.585 kg/m^3 in the TTU d~~D~~istrict (2010), while the lowest was 0.225 kg/m^3 in the Belu district (2012). Average~~ing~~ TFP growth was 0.996, equal with efficiency change (EFC) and technology change (TEC), which was 1.000. However, during this~~e~~ period, there were ~~a~~ decreases~~ing~~ in~~of~~ TFP, EFC, and TEC by 5.949%, 0.557%, and 5.422%, respectively. T~~Concerning~~ he location of the Kupang municipal had the highest TFP growth (1.005), while the Belu district had the lowest (0.990). Corn production technology should be improved, while increasing water use~~s~~ efficiency to boost and sustain corn production.

INTRODUCTION

Corn (Zea mays L.) is one of the main crops cultivated in the world, besides rice, wheat, and potatoes [1]. Corn is the most popular crop for farmers in the West Timor region. Despite ~~there was~~ an increase in corn production ~~by~~ of 1% per year, during 2003 and 2013, there was a reduction ~~of~~ in corn household~~s~~ by 1.96% [2]. Corn was cultivated in the semi-arid region of West Timor, mostly by traditional subsistence farmers. Most of the farmers were using local seed (93%), doing manual land preparation (95%), ~~less~~ using less chemical fertilizer (15%), using low pest control (23%), and doing manual and self-harvesting (98%)~~,~~ and mostly for household~~s~~ consumption (87%). As a consequence of the farming system, corn production is prone to natural hazards, such as high intensities~~y~~ of rain and drought, leading to a jeopardizing of the potential production [2]. As a prominent crop, corn production has been a backbone of food security for the West Timor population. ~~There is~~ H~~h~~owever, based on world food assessments in 2015, ~~there was a~~ 30% of its sub-districts ~~-~~were categorized ~~in~~ as having moderate to high~~ly~~ vulnerability~~le~~ to food security [3]. ~~Even thou~~Although corn is ~~as~~ a C4 crop that is resistant~~ce~~ to drought, water ~~have becoming~~became a major constraint to increase corn production in the semi-arid area. ~~Nowadays~~Today, it is widely believed that ~~to~~ boosting crop production with less water could be achieved ~~by~~ through ~~the~~ an increase ~~of~~ in crop water productivity [4].

Water productivity ~~that~~ was first introduced~~s~~ in 1999, with regards to the physical term ~~is~~ being defined as a unit of production per volume of water use [5]. Furthermore, this notion means an enhancement of crop production with less water. This could be achieved ~~by~~ through ~~the~~ an increase ~~of~~ in crop production, with the same unit of water use~~,~~ or by production of the same amount of food with less water [6]. The idea ~~is~~ has been reshaped by ~~many~~ several studies worldwide;~~,~~ however, ~~there is~~ very limited information exists regarding the growth of water productivity, let alone whether the growth is affected by water use efficiency or by the improvement of production technology.

Modern productivity analysis ~~is~~ takes~~ing~~ into account total factor productivity (TFP) growth, which ~~that also~~ can also provide information regarding whether the growth is predisposed by efficiency growth and technology growth [7]. The M~~M~~almquist index is the most popular method; the method ~~could~~ can be calculated not only based on a non-parametric approach~~ed~~, such as data envelopment analysis (DEA), but also based on a parametric approach~~ed~~, such as stochastic frontier analysis (SFA) [8]. SFA was first proposed in 1977, either by Aigner, Lovell and Schmidts, or~~-~~ Meeusen and van den Broeck, almost ~~at the same time~~simultaneously. One feature of these models is that they have a composed error structure consisting of two variables: one random variable that captures noise and another ~~one~~ that explains technical inefficiency [9].

Furthermore, t~~T~~his study ~~furthermore was~~ intends~~ed~~ to make a remarkable contribution ~~to~~ by providing~~e~~ valuable information, both concerning ~~the~~ corn water productivity (WP$_{Corn}$) by traditional subsistence farming systems in ~~the~~ semi-arid regions and ~~the~~ information regarding ~~the~~ growth with ~~its~~ the component of efficiency and production technology. The aims of this study were to estimate WP$_{Corn}$ ~~corn water productivity subsequently~~ to subsequently estimate ~~total factor productivity~~TFP growth, includinge its components of efficiency change and technology change.

EXPERIMENTAL DETAIL

The research~~ed~~ was conducted in the West Timor region, ~~that~~ part of ~~t~~The East Nusa Tenggara p~~P~~rovince of Indonesia. The astronomical location was ~~in~~ 1230 27' 40" – 1250 11' 59" East Longitude and 080 56' 17" – 100 21' 56" South Latitude. The W~~W~~est Timor region consists of four districts:~~,~~ ~~i.e.~~ Kupang, TTS, TTU, and Belu, ~~and~~ as well as a municipal, i.e., Kupang.

West Timor has ~~the~~ a semi-arid climate that is characterizedstic by a long dry season from April to November that inflictsed monsoons from Australia ~~by~~ in the south-east ~~monsoons from Australia~~. T, ~~t~~he long drought period ~~would~~ harms crop growth and production [10]. Furthermore, FAO stated that semi-arid areas covering 40% of land worldwide and 37% of inhibited ~~land~~ in this world. The semi-arid region features includeing irregular precipitation, long drought periods, evaporation rates exceeding precipitation, and steppe vegetation [11].

There were four steps in this research: first, ~~included~~ a ~~firstly~~ corn water use (CWU_{Corn}) estimate; secondly, a corn water productivity (WP_{Corn}) estimate; thirdly, WP_{Corn} total factor productivity (TFP) growth; and ~~the~~ fourthly, ~~was~~ a chain indices estimate. CWU_{Corn} ~~Corn water use~~ was estimated based on the modified method from [12, 13, 14, and 15], which is ~~that~~ stated in the following formula.

$$CWU_{Corn} = HA_{corn}\left[\sum_{j\varepsilon mth}\sum_{i\varepsilon period}\min\left(Kc_{corn\,i} \times ETo_j, EFFRF_j\right) \times \frac{d_{ij}}{n_j} + \sum_{j\varepsilon mth}\sum_{i\varepsilon period}\left(Kc_{corn\text{-}i} \times ETo_j\right) \times \frac{d_{ij}}{n_j}\right] \quad (1)$$

wWhere~~,~~ HA_{Corn} is the harvested area of ~~-~~corn,~~.~~ $Kc_{corn\text{-}i}$ is the crop coefficients of corn, and~~.~~ ETO_j and $EFFRF_j$ are references of evapotranspiration and effective rainfall, respectively.

The area of harvested cCorn data ~~harvested area was~~were from the provincial statistical bureau publication [2]. Effective rainfall was estimated based on a 75% ~~percent exceedance~~exceeding probability of monthly rainfall [14,15]. Reference evapotranspiration was estimated based on the FAO Penman-Montieth method, with the help of ETO Calculator Version 3.2 [16]. The cCorn coefficient was provided by the Water Resources Directorate of Indonesia. The average crop planting time was from [17]. ~~Corn water productivity (~~WP_{Corn}~~)~~ was calculated based on [5], which ~~that~~ fulfills the following equation.

$$WP_{corn} = \frac{\text{Corn Production (kg kernel)}}{CWU_{Corn}(m^3)} \quad (2)$$

Total factor productivity growth of WP_{Corn} was estimated ~~with~~ using the Stochastic Frontier Analysis-—Malmquist Index (SFA-MI) method. We applied translog production function with balance panel data mean difference input, with ~~;~~ time-variant and truncated normal distribution [18]. The translog production function form was as follow.

$$\ln q_{it} = \beta_0 + \beta_1 \ln x_{it} + \beta_2 t + \beta_3\left(0{,}5 \ln x_{it}^2\right) + \beta_4 \ln x_i\, t + \beta_5\left(0{,}5\, t^2\right) + v_{it} - u_{it} \quad (3)$$

wWhere~~,~~ q_{it} = corn production in each district each year,~~;~~ $x = CWU_{Corn}$,~~;~~ t = time (1, 2 … 16),~~;~~ β_0 to β_5 = model coefficients,~~;~~ v_{it} = random error,~~;~~ and u_{it} = inefficiency effect ~~that~~ assumed ~~has~~ to have a truncated normal distribution.

The technical efficiency change (EFC) was calculated as a function of u_{it}. The technology change (TEC) ~~is~~ was calculated as the geometric mean of two partial derivatives of the production function with time. TFP is widely used in productivity measurement. In the Malmquist index method, TFP is satisfied withying the following formula [19].

$$TFP_t = EFC_t \times TEC_t \quad (4)$$

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Furthermore, in order to capture the changing of WP$_{Corn}$ TFP change during the period of 2000– to 2015, we applied chain indices with the a base period of 2000. The chain indices were estimated based on the following formula [20].

$$I_t = \left(X_t / X_{t-1} \right) I_{t-1} \tag{5}$$

wWhere, 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} = iIndex at time t-1.

RESULT AND DISCUSSION

Corn Production

The cCorn harvested area in West Timor from 2000– to 2015 was fluctuated with a decreasing trend, except for the TTS dDistrict and the TTU dDistrict. The TTS district had the largest, while the Kupang municipal had the least corn harvested area. On the other hand, the TTS district had the lowest fluctuation, as indicated by the coefficient of variance (CV = 16%), while the Kupang municipal had a higher fluctuation (CV= 19%). The cCorn harvested areas in West Timor is are depicted in Figure 1.

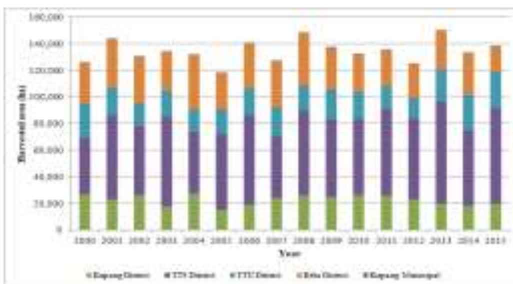

FIGURE 1. Corn harvested area in West Timor region during 2000–-2015

To some degree, as a consequence of corn harvested area fluctuation, corn production, in terms of corn kernel during 2000– to 2015, fluctuated. According to [10], due to traditional farming that dominated by through the shifting and cultivation method in a semi-–arid climate like West Timor, crop production prone to natural disaster leading to crop failure as frequent as one year in five. However, farmers in the TTS dDistrict and the TTU district, through this period, could manage to increase the production. The TTS district was a leading corn producer, while the Kupang municipal was the least smallest corn producer. The Belu district was a second highest producer, with the highest fluctuation (CV = 29.6%), and the Kupang district as was the third producer and had the lowest fluctuation (CV= 17%).

According to [21, 22], in from an anthropologicaly perspective, farmers in West Timor cultivated corn earlier than rice. Corn farmers still maintain some rituals during the cultivation process. Corn was planted particularly in particularly areas distantce from residencestial areas (in *Kebun*) that were appointed by tribales leaders. In terms of geomorphology, corn was mostly planted in dry land and hilly contour. The island of Timor is also strongly affected by the El Niño Southern Oscillation (ENSO) cycle.

In the period of 2000—2015, West Timor farmers, on in average, were producinged 331,000 tons of corn kernel annually. The maximum production was in 2013 (403.4 thousand tons), and the lowest was in 2011 (254.3 thousand tons). The TTS district was contributed 43.68%, the Belu dDistricts provided 21.72%, the Kupang district subscribed 16.49%, the TTU district produced 14.93% and, the leastlowest producer, the Kupang municipal contributed 3.18%. Corn kernel production in 2000—2015 is presented in Figure 2.

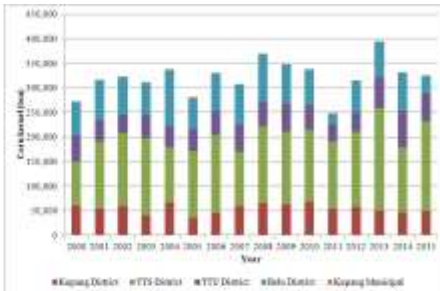

FIGURE 2. Corn kernel production in West Timor in 2000—2015

Corn Water Use

The main source of water for corn cultivation is from rainfall. This green water is the prominent factor for corn production in West Timor. Corn planting time was adjusted to the rainfall condition that varies from November to March each year. The peak planting season is usually in January and February, when rainfall is ~~in~~ at its peak season, and soil moisture is sufficient for corn seed to grow.

In the period of 2000—2015, ~~corn water use (~~CWU_{Corn}~~)~~ ~~was~~ fluctuated,~~ion~~ and ~~at~~ in 2015, there ~~were~~ was a decline~~ing~~ in the Kupang district, the Belu district, and the Kupang municipal. Average~~ing~~ water use for corn cultivation in West Timor during this ~~e~~ period was 414.85 million m^3 per annum. It r~~R~~eached a peak in 2013 (545.83 Mm^3), and the lowest was in 2005 (345.91 Mm^3). The TTS district utilized 45.80%, followed by the Belu district, which ~~that~~ used 22.91%.~~;~~ The Kupang district used 16.84%, the~~;~~ TTU district utilized 14.10%, and the Kupang municipal used 0.34%. The TTU district ~~was more~~ fluctuated more, and the least fluctuat~~inged~~ was the Kupang municipal. ~~Corn water use (~~CWU_{Corn}~~)~~ of the West Timor region in 2000–2015 is presented in Table 1.

TABLE 1. West Timor region's- c~~C~~orn water use (m~~M~~illion m^3) during 2000–2015

Year	Kupang District	TTS District	TTU District	Belu District	Kupang Municipal	West Timor Region
2000	78.59	126.45	67.33	84.08	1.51	357.97
2001	69.79	188.74	51.94	108.61	1.59	420.67
2002	76.80	158.79	49.17	102.92	1.52	389.20
2003	52.81	211.48	54.02	85.81	1.55	405.67
2004	82.30	143.48	47.48	114.91	1.79	389.96
2005	44.44	176.12	47.78	75.94	1.62	345.91
2006	56.63	203.69	59.95	101.78	1.64	423.69
2007	69.93	136.13	58.24	103.36	1.35	369.01
2008	85.56	200.50	57.54	121.45	1.46	466.51
2009	69.40	169.74	54.25	90.41	1.36	385.16
2010	70.28	174.38	32.02	84.88	0.90	362.46
2011	89.81	232.61	45.43	96.48	1.08	465.41
2012	88.53	226.66	61.31	94.50	1.45	472.46
2013	70.95	283.26	90.78	99.48	1.37	545.83
2014	57.06	184.02	80.50	100.12	1.05	422.76
2015	55.09	224.22	78.16	56.17	1.21	414.85
Total	**1,117.98**	**3,040.28**	**935.91**	**1,520.91**	**22.45**	**6,637.52**
Average	**69.87**	**190.02**	**58.49**	**95.06**	**1.40**	**414.85**
Std. Deviation	**13.58**	**40.62**	**14.78**	**15.72**	**0.24**	**52.25**
Coefficient of variance (%)	**19.44**	**21.38**	**25.28**	**16.54**	**17.20**	**12.60**

CWU_{Corn} ~~Corn water use~~ by farmers in West Timor was similar to that in India and Bangladesh. ~~The~~ A study in India reported that CWU_{Corn} reached 2,264 m^3/ha [13], while in Bangladesh, it ~~was~~ reached 1,430 m^3/ha [23]. In West Timor, the value was 3,079.13 m^3/ha. The result revealed that there were considerable opportunities to promote water-–saving strategiesy for corn farmers in the developing world, particularly in a semi-arid regions like such as West Timor.

Corn Water Productivity

Corn water productivity (WP$_{Corn}$) in West Timor during 2000–-2015 showed a fluctuation trend. The most fluctuatinged were the TTU district in 2010 and the Belu dDistrict in 2011. The average WP$_{Corn}$ of West Timor was 0.782 kg kernel/m^3, the highest value was in the TTU district in 2010 (1.585 kg kernel/m^3), and the lowest was in the Belu district in 2011 (0.225 kg kernel/m^3). The TTU district, furthermore, had the highest average WP$_{Corn}$ (0.873 kg kernel/m^3),; the Kupang district had the an average WP$_{Corn}$ of 0.798 kg kernel/m^3), while the TTS district, which that contributed the majority of corn production in the region, had the a WP$_{Corn}$ of 0.768 kg kernel/m^3. The Belu district and the Kupang municipal were had the a WP$_{Corn}$ of 0.752 kg kernel/m^3 and 0.751 kg kernel/m^3–, respectively.

It is interesting to note that WP$_{Corn}$ in the West Timor region was tantamount to each district regarding the great disparities in harvested area and production. This indicator expressed the efficiency and affectivity of water use to produce corn kernel. This result, furthermore, explained that the capacity of farmers in West Timor in using water for corn production was alike. This could be explained by the fact that in the traditional farming system, the capacity of farmers in managing water for food is similar; the slightly differencet was probably due to soil and topography condition, local climate, pests, and other factors. The West Timor WP$_{Corn}$ in the last decade is depicted in Figure 3.

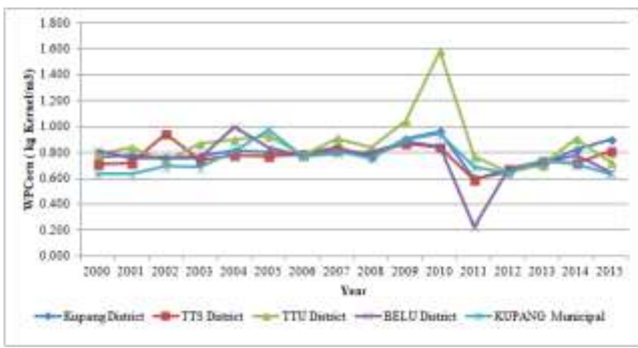

FIGURE 3. Corn wWater pProductivity (-WP$_{Corn}$) of West Timor during 2000–—2015

The value of WP$_{Corn}$ in West Timor was in the range with of what was reported worldwide. The lowest value of WP$_{Corn}$ is was 0.03 kg/m^3-, that cultivated in Gainesville, FL, US,A without irrigation and fertilizer, as reported by [24]. The highest value is was 7.160 kg/m^3-, that cultivated in Nebraska, US,A with a pivot irrigation system [25]. The average value of WP$_{Corn}$ that was cultivated in dry lands of semi-arid regions is was 0,143 kg/m^3 - 1,000 kg/m^3-, as reported by [26].

Corn Water Productivity Growth

The calculation of SFA-MI was done with the help of FRONTIER 4.1. The sSoftware was freely provided by the center of productivity analysis of Queensland University Australia [27]. The model coefficient of the translog production function expressed that water was a significant factor at the level of 1% in corn production. Moreover, that this curvature form of water and time were was also a significant- factors at the level of 10%. Sigma squared (σ2) indicated total variance was lower and not significant. Gamma (γ), which that indicated the ratio of inefficiency effect to total variance, showed a low value and was insignificant; this implied that the efficiency effect is relatively small. Mu (μ) ~~that~~ indicated that the inefficiency effect was small and concentrated near 0. Eta (η) was negative, small, and not significant, indicating~~ed~~ that the inefficiency effect was narrow, with an increase overtime, but was not prominent. The parameter of the estimated translog production function is reported in Table 2.

Average~~ing~~ corn total water productivity (WP_{Corn} TFP) showed a decline in efficiency, technology, and total factor productivity growths. Mean efficiency and total factor productivity growth indexes were 0.996, whereas the technology progress index was 1.000. Worth noting ~~this~~ is that the results expressed that during the last 16 years in West Timor, the traditional corn cultivation system was considerably~~e~~ efficient in using water, while production technology progress was comparatively stagnant.

TABLE 2. Stochastic frontier approximation of corn production in West Timor in 2000–2015

Components	Coefficient	t-ratio
Intercept	1.48E-01	2.153**
ln CWU_{Corn}	9.55E-01	32.224***
Time	-4.47E-05	-0.006
ln CWU_{Corn}^2	-4.56E-02	-1.874*
ln CWU_{Corn} * Time	-2.59E-03	-0.975
$Time^2$	-3.99E-03	-1.729*
Sigma-squared (σ2)	5.76E-02	0.304
Gamma (γ)	4.01E-01	0.203
Mu (μ)	-1.87E-01	-0.067
Eta (η)	-1.07E-01	-0.926

Note: ***, **, and * indicate~~d~~ significant levels at 1%, 5%, and 10%, respectively.

The fact that traditional corn farmers were relatively efficient in using water for corn production given the current technology ~~was~~, in some degree, departed from the common perspective that traditional farmers in the semi-arid region were not efficient in using water. H~~There is h~~owever, the stagnation of corn cultivation process was apprehensible due to the limitation of farmers to gain modern technology and other production inputs. WP_{Corn} TFP growth during this~~e~~ period is presented in Table 3.

TABLE 3. Corn total water productivity growth of the West Timor r~~R~~egion ~~at~~ in 2000–2015

Year	Efficiency change (EFC)	Technology change (TEC)	Total factor productivity change (TFPC)
2000–2001	0.998	1.028	1.026
2001–2002	0.998	1.024	1.022
2002–2003	0.998	1.020	1.018
2003–2004	0.998	1.016	1.014
2004–2005	0.997	1.012	1.010
2005–2006	0.997	1.008	1.005
2006–2007	0.997	1.004	1.001
2007–2008	0.997	1.000	0.996
2008–2009	0.996	0.996	0.992
2009–2010	0.996	0.992	0.988
2010–2011	0.995	0.988	0.984
2011–2012	0.995	0.984	0.979
2012–2013	0.994	0.980	0.974
2013–2014	0.994	0.976	0.969
2014–2015	0.993	0.972	0.965
Mean	**0.996**	**1.000**	**0.996**

In total factor productivity (TFP) analysis, we could extract the growth components of efficiency change and technology change. The TFP growth moreover could be achieved not only ~~by~~ through the enhancement of efficiency change (catch up) but also by a positive sifting of the production frontier through the improvement of production technology [8,28]. This result exhibited that ~~there were~~ opportunities exist to upgrade water use efficiency by 3.4% at the current level of technology and~~,~~ likewise, to advance corn production technology.

To explain the growth over time, chain indices with ~~the~~ a base year of 2000 that had the index value~~s~~ of 1.000 was applied. During the period, it was clear that the TFP growth was determined by the decrease ~~of~~ in technology change, rather than the slight decrease in efficiency change. There was a 0.56% reduction of in efficiency change and; a 5.42% reduction of in technology change, which; that affectedresulted in a 5.95% reduction of in TFP. It is important to note that the growth dwindle was alarming. NowadaysToday, there is a continued high demand fored food production due to population growth under the degradation of natural resources. So thatThus, there should be necessary affords to tackle the downfall WP$_{Corn}$ TFP. The chain index of TFP is presented in Figure 4.

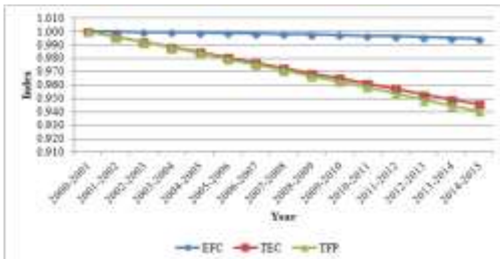

FIGURE 4. Chain indices of WP$_{Corn}$ TFP growth of West Timor during 2000–—2015

TConsidering he districts' performance, it showed that the smaller producer possessed better growth. Despite the TTS district and the TTU district were havinge a better efficiency change, the Kupang municipal was possessed better technology progress, leading to had better TFP growth. It was understandable that as a capital city of the province, the farmers preferredable to get obtain better information and better input. Additionally, farmers in the municipal had a better socio-economicy levelstatus. The dDistricts' WP$_{Corn}$TFP growth is are depicted in Figure 5.

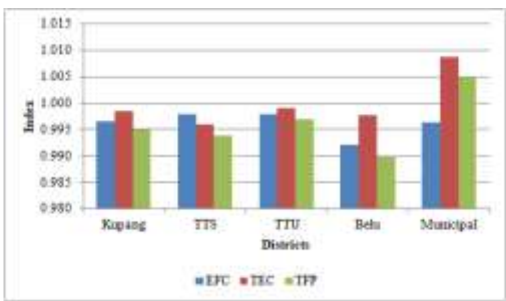

FIGURE 5. Mean dDistricts' WP$_{Corn}$ TFP gGrowth during 2000–—2015

SUMMARY

Corn, as a major crop for farmers in West Timor, is cultivated in through the traditional subsistence system. There was a fluctuation in harvested area, production, and water use. Corn water use was differedent across time and districts. Due to the fluctuation of in production and water use, corn water productivity fluctuated over time and districts. The cCorn water productivity value was in range with other reports worldwide, particularly in the semi-arid regions. Stochastic translog production function explained that water, in terms of volumetric water use, was the notable factor. Besides that Wwater and time were hadve a quadratic influence over corn production. With regard to corn total water productivity growth, oin average, farmers in the region were considerablye efficient in used water for corn production, but the technology did not progress. During the period, all the productivity measures, namely efficiency change, technology change, and total factor productivity change, were subsided. The degradation of in technological change more was steeper than that of efficiency;, therefore, the technology change determined the TFP growth. Considering food security, there should be an advance in corn water use efficiency and production technology. With regard to the performance of the districts, theyit exhibited the growth, regardless of the scale of production but, rather, the quality of the process. Besides environment and climate, other elements influenced the water productivity growth, such as access to better information, technology, production inputs, and farmers' socio-economicy conditions.

Corn Water Productivity growth using Stochastic Frontier Analysis – Malmquist Index (A case of West Timor – Indonesia)

Comment [U1]: Use AIP template
-conclusion is too long

Jonathan E. Koehuan[1,2, a)], Bambang Suharto[1,b)], Gunomo Djoyowasito[1,c)] and Liliya D. Susanawati [1,d)]

[1] Department of Agricultural Engineering, Brawijaya University, Malang, Indonesia
[2]Department of Agricultural Engineering, Artha Wacana Christian University, Kupang, Indonesia

[a)]Corresponding author: jekoehuan@gmail.com
[b)] bambangs@ub.ac.id
[c)] djoyowasitogunomo@yahoo.com
[d)] liliya_10@ub.ac.id

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Abstract. Corn is one of the most popular crop worldwide includes for the West Timor farmers. However, there is a very limited report on corn water productivity growth. This research would make a remarkable contribution to fill the gap. This study aims to estimate corn water productivity (WP_{Corn}) of West Timor subsequently to determine its total factor productivity (TFP) growth during 2000-2015. To doing so, we used 16 years of balanced panel data of climate and crop data. WP_{Corn} was estimated based on corn water use (CWU_{Corn}). Then SFA-MI was applied to determine TFP growth. The results showed that mean WP_{Corn} in this region was 0.782 kg/m^3 water use, the highest was 1.585 kg/m^3 in TTU District (2010) while the lowest was 0.225 kg/m^3 in Belu district (2012). Averaging TFP growth was 0.996 equal with efficiency change (EFC) and technology change (TEC) was 1.000. However, during the period there were a decreasing of TFP, EFC, and TEC by 5.949%, 0.557%, and 5.422% respectively. Concerning location Kupang municipal had the highest TFP growth (1.005) while Belu district had the lowest (0.990). Corn production technology should be improved while increasing water uses efficiency to boost and sustain corn production.

INTRODUCTION

Corn (Zea mays L.) is one of the main crops cultivated in the world beside rice, wheat and potato [1]. Corn is the most popular crop for farmers in West Timor region. Despite there was an increase in corn production by 1% per year, during 2003 and 2013 there was a reduction of corn households by 1.96% [2]. Corn was cultivated in the semi-arid region of West Timor mostly by traditional subsistence farmers. Most of the farmers using local seed (93%), doing manual land preparation (95%), less using chemical fertilizer (15%), low pest control (23%), doing manual and self-harvesting (98%), and mostly for households consumption (87%). As a consequence of the farming system, corn production is prone to natural hazards such as high intensity of rain and drought leading to jeopardizing the potential production [2]. As a prominent crop, corn production has been a backbone of food security for West Timor population. There is however based on world food assessment in 2015, there was a 30% of its sub-district categorized in moderate to highly vulnerable to food security [3]. Even thou as a C4 crop that resistance to drought, water have becoming a major constraint to increase corn production in the semi-arid area. Nowadays, it is widely believed that to boost crop production with less water could be achieved by the increase of crop water productivity [4].

Water productivity that first introduces in 1999, with regards to physical term is defined as a unit of production per volume water use [5]. Furthermore, this notion means an enhancement of crop production with less water. This could achieve by the increase of crop production with the same unit of water use, or by production the same amount of food with less water [6]. The idea is reshaped by many studies worldwide, however, there is very limited information regarding the growth of water productivity let alone whether the growth is affected by water use efficiency or by the improvement of production technology.

Modern productivity analysis is taking into account total factor productivity (TFP) growth that also can provide information regarding the growth is predispose by efficiency growth and technology growth [7]. Malmquist index is the most popular method; the method could be calculated not only based on non-parametric approached such as data envelopment analysis (DEA) but also based on parametric approached such as stochastic frontier analysis (SFA) [8]. SFA was first proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) almost at the same time. One feature of these models is that they have a composed error structure consisting of two variables: one random variable that captures noise and another one that explains technical inefficiency [9].

Comment [DW3]: Use numbering system

This study furthermore was intended to make a remarkable contribution to provide valuable information both concerning the corn water productivity by traditional subsistence farming system in the semi-arid region and the information regarding the growth with its component of efficiency and production technology. The aims of this study were to estimate corn water productivity subsequently to estimate total factor productivity growth include its components of efficiency change and technology change.

METHOD

Comment [DW4]: Experimental detail

The researched was conducted in West Timor region, that part of The East Nusa Tenggara Province of Indonesia. The astronomical location was in 1230 27' 40" – 1250 11' 59" East Longitude and 080 56' 17" – 100 21' 56" South Latitude. West Timor region consists of four districts, i.e. Kupang, TTS, TTU and Belu, and a municipal, i.e. Kupang.

West Timor has the semi-arid climate that characteristic by a long dry season from April to November that inflicted by south-east monsoons from Australia, the long drought period would harm crop growth and production [10]. Furthermore, FAO stated that semi-arid area covering 40% of land worldwide and 37% inhibited land in this world. The semi-arid region features including irregular precipitation, long drought periods, evaporation rates exceeding precipitation, and steppe vegetation [11]

There were four steps in this research included firstly corn water use (CWU_{Corn}) estimate; secondly corn water productivity (WP_{Corn}) estimate; thirdly WP_{Corn} total factor productivity (TFP) growth; and the fourth was chain indices estimate. Corn water use was estimated based on the modified method from [12, 13, 14, and 15] that stated in the following formula.

$$CWU_{Corn} = HA_{corn}\left[\sum_{j\varepsilon mth}\sum_{i\varepsilon period}\min\left(Kc_{corn\ i}\ x\ ETo_j, EFFRF_j\right) x\ \frac{d_{ij}}{n_j} + \sum_{j\varepsilon mth}\sum_{i\varepsilon period}\left(Kc_{corn\text{-}i}\ x\ ETo_j\right) x\ \frac{d_{ij}}{n_j}\right] \quad (1)$$

Where, HA_{Corn} is harvested area of corn. $Kc_{corn\text{-}i}$ is crop coefficients corn. ETO_j and $EFFRF_j$ are references of evapotranspiration and effective rainfall respectively.

Corn harvested area was from the provincial statistical bureau publication [2]. Effective rainfall was estimated based on a 75 percent exceedance probability of monthly rainfall [14,15]. Reference evapotranspiration was estimated based on FAO Penman-Montieth method with the help of ETO Calculator Version 3.2 [16]. Corn coefficient was provided by the Water Resources Directorate of Indonesia. The average crop planting time was from [17]. Corn water productivity (WP_{Corn}) was calculated based on [5] that fulfill the following equation.

$$WP_{corn} = \frac{\text{Corn Production (kg kernel)}}{CWU_{Corn}(m^3)} \quad (2)$$

Total factor productivity growth of WP_{Corn} was estimated with the Stochastic Frontier Analysis – Malmquist Index (SFA-MI) method. We applied translog production function with balance panel data mean difference input; time-variant and truncated normal distribution [18]. The translog production function form was as follow.

$$\ln q_{it} = \beta_0 + \beta_1 \ln x_{it} + \beta_2 t + \beta_3\left(0{,}5 \ln x_{it}^2\right) + \beta_4 \ln x_i\ t + \beta_5\left(0{,}5\ t^2\right) + v_{it} - u_{it} \quad (3)$$

Where, q_{it} = corn production in each district each year; x = CWU_{Corn} ; t = time (1, 2 … 16); β_0 to β_5 = model coefficients; v_{it} = random error ; and u_{it} = inefficiency effect that assumed has a truncated normal distribution.

The technical efficiency change (EFC) was calculated as a function of u_{it}. The technology change (TEC) is calculated as the geometric mean of two partial derivatives of the production function with time. TFP is widely used in productivity measurement. In the Malmquist index method, TFP is satisfying the following formula [19].

$$TFP_t = EFC_t \times TEC_t \tag{4}$$

Furthermore, in order to capture the changing of WP_{Corn} TFP change during the period of 2000 to 2015, we applied chain indices with the base period of 2000. The chain indices were estimated based on the following formula [20].

$$I_t = \left(X_t / X_{t-1}\right) I_{t-1} \tag{5}$$

Where, I_t = index at the time t, X_t = value at time t, X_{t-1} = value at time t-1, I_{t-1}= Index at time t-1

RESULT AND DISCUSSION

Corn Production

Comment [DW5]: It is not AIP style

Corn harvested area in West Timor from 2000 to 2015 was fluctuated with a decreasing trend except for TTS District and TTU District. TTS district had the largest while Kupang municipal had the least corn harvested area. On the other hand, TTS district had the lowest fluctuation indicated by the coefficient of variance (CV = 16%) while Kupang municipal had a higher fluctuation (CV= 19%). Corn harvested areas in West Timor is depicted in Figure 1.

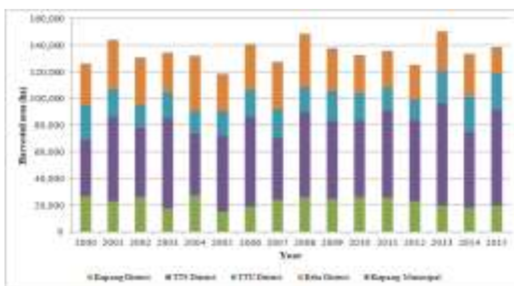

FIGURE 1. Corn harvested area in West Timor region during 2000 - 2015

To some degree as a consequence of corn harvested area fluctuation, corn production in terms of corn kernel during 2000 to 2015 fluctuated. According to [10] due to traditional farming that dominated by shifting and cultivation method in a semi arid climate like West Timor, crop production prone to natural disaster leading to crop failure as frequent as one year in five. However, farmers in TTS District and TTU district, through this period could manage to increase the production. TTS district was a leading corn producer while Kupang municipal was the least corn producer. Belu district was a second producer with highest fluctuation (CV = 29.6%) and Kupang district as the third producer had the lowest fluctuation (CV= 17%).

According to [21, 22] in anthropology perspective farmers in West Timor cultivated corn earlier than rice. Corn farmers still maintain some rituals during the cultivation process. Corn was planted in particularly areas distance from residential areas (in *Kebun*) that appointed by tribes leader. In terms of geomorphology, corn was mostly planted in dry land and hilly contour. The island of Timor also strongly affected by the El Niño Southern Oscillation (ENSO) cycle.

In the period of 2000 – 2015, West Timor farmers in average were produced 331,000 ton corn kernel annually. The maximum production was in 2013 (403.4 thousand ton) and the lowest in 2011 (254.3 thousand ton). TTS district was contributed 43.68%, Belu Districts provided 21.72%, Kupang district subscribed 16.49%, TTU district produced 14.93% and the least the Kupang municipal contribute 3.18%. Corn kernel production in 2000 – 2015 is presented in Figure 2.

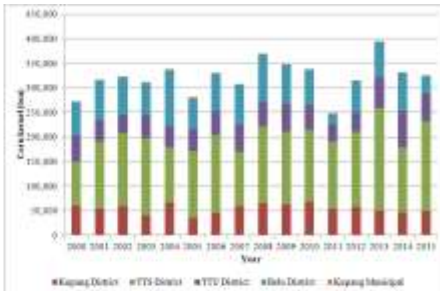

FIGURE 2. Corn kernel production in West Timor in 2000 – 2015

Corn Water Use (CWU_{Corn})

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The main source of water for corn cultivation is from rainfall. This green water is the prominent factor for corn production in West Timor. Corn planting time was adjusted to the rainfall condition that varies from November to March each year. The peak planting season is usually in January and February when rainfall is in peak season and soil moisture is sufficient for corn seed to grow.

In the period of 2000 – 2015, corn water use was fluctuation and at 2015 there were a declining in Kupang district, Belu district and Kupang municipal. Averaging water use for corn cultivation in West Timor during the period was 414.85 million m^3 per annum. Reached a peak in 2013 (545.83 Mm^3) and the lowest was in 2005 (345.91 Mm^3). TTS district utilized 45.80% followed by Belu district that used 22.91%; Kupang district used 16.84%; TTU district utilized 14.10%, and Kupang municipal used 0.34%. TTU district was more fluctuate and the least fluctuated was Kupang municipal. Corn water use (CWU_{Corn}) of West Timor region in 2000-2015 is presented in Table 1.

TABLE 1. West Timor region's Corn water use (Million m^3) during 2000 - 2015

Year	Kupang District	TTS District	TTU District	Belu District	Kupang Municipal	West Timor Region
2000	78.59	126.45	67.33	84.08	1.51	357.97
2001	69.79	188.74	51.94	108.61	1.59	420.67
2002	76.80	158.79	49.17	102.92	1.52	389.20
2003	52.81	211.48	54.02	85.81	1.55	405.67
2004	82.30	143.48	47.48	114.91	1.79	389.96
2005	44.44	176.12	47.78	75.94	1.62	345.91
2006	56.63	203.69	59.95	101.78	1.64	423.69
2007	69.93	136.13	58.24	103.36	1.35	369.01
2008	85.56	200.50	57.54	121.45	1.46	466.51
2009	69.40	169.74	54.25	90.41	1.36	385.16
2010	70.28	174.38	32.02	84.88	0.90	362.46
2011	89.81	232.61	45.43	96.48	1.08	465.41
2012	88.53	226.66	61.31	94.50	1.45	472.46
2013	70.95	283.26	90.78	99.48	1.37	545.83
2014	57.06	184.02	80.50	100.12	1.05	422.76
2015	55.09	224.22	78.16	56.17	1.21	414.85
Total	**1,117.98**	**3,040.28**	**935.91**	**1,520.91**	**22.45**	**6,637.52**
Average	**69.87**	**190.02**	**58.49**	**95.06**	**1.40**	**414.85**
Std. Deviation	**13.58**	**40.62**	**14.78**	**15.72**	**0.24**	**52.25**
Coefficient of variance (%)	**19.44**	**21.38**	**25.28**	**16.54**	**17.20**	**12.60**

Corn water use by farmers in West Timor was similar to in India and Bangladesh. The study in India reported that CWU_{Corn} reached 2,264 m^3/ha [13], while in Bangladesh it was reached 1,430 m^3/ha [23]. In West Timor, the value was 3,079.13 m^3/ha. The result revealed that there were considerable opportunities to promote water saving strategy for corn farmers in the developing world particularly in a semi-arid region like West Timor.

Corn Water Productivity (WP_{Corn})

Comment [DW7]: Use AIP style

Corn water productivity in West Timor during 2000-2015 showed a fluctuation trend. The most fluctuated were TTU district in 2010 and Belu District in 2011. The average WP_{Corn} of West Timor was 0.782 kg kernel/m^3, the highest value was in TTU district in 2010 (1.585 kg kernel/m^3) and the lowest was in Belu district in 2011 (0.225 kg kernel/m^3). TTU district furthermore had the highest average WP_{Corn} (0.873 kg kernel/m^3); Kupang district had the average WP_{Corn} of 0.798 kg kernel/m^3) while TTS district that contributed the majority of corn production in the region had the WP_{Corn} of 0.768 kg kernel/m^3. Belu district and Kupang municipal were had the WP_{Corn} of 0.752 kg kernel/m^3 and 0.751 kg kernel/m^3 respectively.

It is interesting to note that WP_{Corn} in West Timor region was tantamount to each district regarding the great disparities in harvested area and production. This indicator expressed the efficiency and affectivity of water use to produce corn kernel. This result furthermore explained that the capacity of farmers in West Timor in using water for corn production was alike. This could be explained by the fact that in the traditional farming system, the capacity of farmers in managing water for food is similar; the slightly different was probably due to soil and topography condition, local climate, pests, and other factors. The West Timor WP_{Corn} in the last decade is depicted in Figure 3.

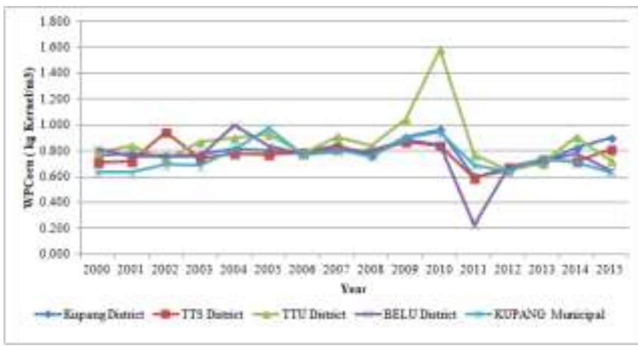

FIGURE 3. Corn Water Productivity (WP_{Corn}) of West Timor during 2000 - 2015

The value of WP_{Corn} in West Timor was in the range with what reported worldwide. The lowest value of WP_{Corn} is 0.03 kg/m^3 that cultivated in Gainesville, FL USA without irrigation and fertilizer as reported by [24]. The highest value is 7.160 kg/m^3 that cultivated in Nebraska USA with pivot irrigation system [25]. The average value of WP_{Corn} that cultivated in dry land of semi-arid region is 0,143 kg/m^3 - 1,000 kg/m^3 as reported by [26].

Corn Water Productivity Growth (WP_{Corn} TFP Growth)

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The calculation of SFA-MI was with the help of FRONTIER 4.1. The Software was freely provided by the center of productivity analysis of Queensland University Australia [27]. The model coefficient of the translog production function expressed that water was a significant factor at the level of 1% in corn production. Moreover, that curvature form of water and time were also significant factors at the level of 10%. Sigma squared ($\sigma 2$) indicated total variance was lower and not significant. Gamma (γ) that indicated the ratio of inefficiency effect to total variance showed a low value and insignificant; this implied that the efficiency effect is relatively small. Mu (μ) that indicated the inefficiency effect was small and concentrated near 0. Eta (η) was negative, small and not significant indicated that inefficiency effect was narrow increase overtime but not prominent. The parameter of the estimated translog production function is reported in Table 2.

Averaging corn total water productivity (WP_{Corn} TFP) showed a decline in efficiency, technology, and total factor productivity growths. Mean efficiency and total factor productivity growth indexes were 0.996 whereas technology progress index was 1.000. Worth noting this results expressed that during the last 16 years in West Timor traditional corn cultivation system was considerable efficient in using water while production technology progress was comparatively stagnant.

TABLE 2. Stochastic frontier approximation of corn production in West Timor 2000-2015

Components	Coefficient	t-ratio
Intercept	1.48E-01	2.153**
ln CWU_{Corn}	9.55E-01	32.224***
Time	-4.47E-05	-0.006
ln CWU_{Corn}^2	-4.56E-02	-1.874*
ln CWU_{Corn} * Time	-2.59E-03	-0.975
$Time^2$	-3.99E-03	-1.729*
Sigma-squared (σ2)	5.76E-02	0.304
Gamma (γ)	4.01E-01	0.203
Mu (μ)	-1.87E-01	-0.067
Eta (η)	-1.07E-01	-0.926

Note: ***,**,and * indicated significant level at 1%, 5% and 10% respectively

The fact that traditional corn farmers relatively efficient in using water for corn production given the current technology was in some degree depart from the common perspective that traditional farmers in the semi-arid region were not efficient in using water. There is however the stagnation of corn cultivation process was apprehensible due to the limitation of farmers to gain modern technology and other production inputs. WP_{Corn} TFP growth during the period is presented in Table 3.

TABLE 3. Corn total water productivity growth of West Timor Region at 2000 - 2015

Year	Efficiency change (EFC)	Technology change (TEC)	Total factor productivity change (TFPC)
2000-2001	0.998	1.028	1.026
2001-2002	0.998	1.024	1.022
2002-2003	0.998	1.020	1.018
2003-2004	0.998	1.016	1.014
2004-2005	0.997	1.012	1.010
2005-2006	0.997	1.008	1.005
2006-2007	0.997	1.004	1.001
2007-2008	0.997	1.000	0.996
2008-2009	0.996	0.996	0.992
2009-2010	0.996	0.992	0.988
2010-2011	0.995	0.988	0.984
2011-2012	0.995	0.984	0.979
2012-2013	0.994	0.980	0.974
2013-2014	0.994	0.976	0.969
2014-2015	0.993	0.972	0.965
Mean	**0.996**	**1.000**	**0.996**

In total factor productivity (TFP) analysis, we could extract the growth components of efficiency change and technology change. TFP growth moreover could be achieved not only by the enhancement of efficiency change (catch up) but also by a positive sifting of the production frontier through the improvement of production technology [8,28]. This result exhibited that there were opportunities to upgrade water use efficiency by 3.4% at the current level of technology, likewise to advance corn production technology.

To explain the growth over time, chain indices with the base year of 2000 that had the index values of 1.000 was applied. During the period it was clear that the TFP growth was determined by the decrease of technology change rather than the slight decrease in efficiency change. There was a 0.56% reduction of efficiency change; a 5.42% reduction of technology change; that affected a 5.95% reduction of TFP. It is important to note that the growth dwindle was alarming. Nowadays, there is a continued high demanded food production due to population growth under the degradation of natural resources. So that, there should be necessary affords to tackle the downfall WP_{Corn} TFP. The chain index of TFP is presented in Figure 4.

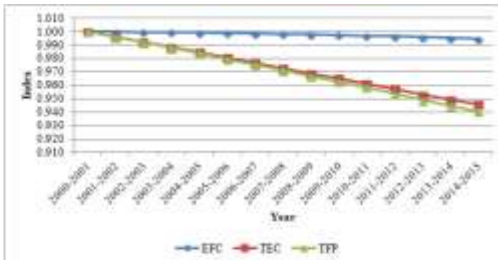

FIGURE 4. Chain indices of WP_{Corn} TFP growth of West Timor during 2000 - 2015

Considering districts performance, it showed that the small producer possessed better growth. Despite TTS district and TTU district were have a better efficiency change, Kupang municipal was possessed better technology progress leading to had better TFP growth. It was understandable that as a capital city of the province, the farmers preferable to get better information and better input. Additionally, farmers in the municipal had a better socio-economy level. Districts WP_{Corn}TFP growth is depicted in Figure 5.

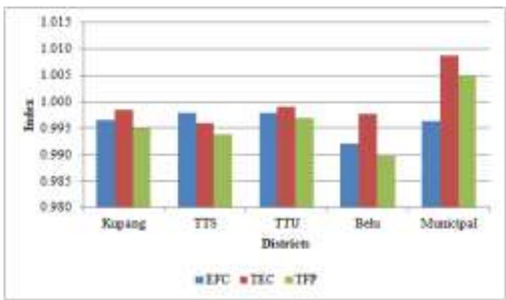

FIGURE 5. Mean Districts WP_{Corn} TFP Growth during 2000 - 2015

CONCLUSION

Comment [d9]: summary

Corn as a major crop for farmers in West Timor is cultivated in traditional subsistence system. There was a fluctuation in harvested area, production and water use. Corn water use was different across time and districts. Due to the fluctuation of production and water use, corn water productivity fluctuated over time and districts. Corn water productivity value was in range with other reports worldwide, particularly in the semi-arid region. Stochastic translog production function explained that water in terms of volumetric water use was the notable factor. Besides that water and time were have a quadratic influence over corn production. With regard to corn total water productivity growth, in average farmers in the region were considerable efficient in used water for corn production but the technology did not progress. During the period all the productivity measures namely efficiency change, technology change, and total factor productivity change were subsided. The degradation of technological change more steep than of efficiency, therefore the technology change determined the TFP growth. Considering food security, there should be an advance in corn water use efficiency and production technology. With regard to the performance of the districts, it exhibited the growth regardless the scale of production but rather the quality of the process. Besides environment and climate, other elements influenced the water productivity growth such as access to better information, technology, production inputs, and farmers' socio-economy conditions.

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Corn Water Productivity growth of West Timor, Indonesia

Jonathan E. Koehuan[1,2, a)], Bambang Suharto[1,b)], Gunomo Djoyowasito[1,c)] and Liliya D. Susanawati [1,d)]

[1] Department of Agricultural Engineering, Brawijaya University, Malang, Indonesia
[2]Department of Agricultural Engineering, Artha Wacana Christian University, Kupang, Indonesia

[a)]Corresponding author: jekoehuan@gmail.com
[b)] bambangs@ub.ac.id
[c)] djoyowasitogunomo@yahoo.com
[d)] liliya_10@ub.ac.id

Abstract. Corn is one of the most popular crop worldwide includes for the West Timor farmers. However, there is a very limited report on corn water productivity growth. This research would make a remarkable contribution to fill the gap. This study aims to estimate corn water productivity (WP_{Corn}) of West Timor subsequently to determine its total factor productivity (TFP) growth during 2000-2015. To doing so, we used 16 years of balanced panel data of climate and crop data. WP_{Corn} was estimated based on corn water use (CWU_{Corn}). Then SFA-MI was applied to determine TFP growth. The results showed that mean WP_{Corn} in this region was 0.782 kg/m^3 water use, the highest was 1.585 kg/m^3 in TTU District (2010) while the lowest was 0.225 kg/m^3 in Belu district (2012). Averaging TFP growth was 0.996 equal with efficiency change (EFC) and technology change (TEC) was 1.000. However, during the period there were a decreasing of TFP, EFC, and TEC by 5.949%, 0.557%, and 5.422% respectively. Concerning location Kupang municipal had the highest TFP growth (1.005) while Belu district had the lowest (0.990). Corn production technology should be improved while increasing water uses efficiency to boost and sustain corn production.

INTRODUCTION

Corn (Zea mays L.) is one of the main crops cultivated in the world beside rice, wheat and potato [1]. Corn is the most popular crop for farmers in West Timor region. Despite there was an increase in corn production by 1% per year, during 2003 and 2013 there was a reduction of corn households by 1.96% [2]. Corn was cultivated in the semi-arid region of West Timor mostly by traditional subsistence farmers. Most of the farmers using local seed (93%), doing manual land preparation (95%), less using chemical fertilizer (15%), low pest control (23%), doing manual and self-harvesting (98%), and mostly for households consumption (87%). As a consequence of the farming system, corn production is prone to natural hazards such as high intensity of rain and drought leading to jeopardizing the potential production [2]. As a prominent crop, corn production has been a backbone of food security for West Timor population. There is however based on world food assessment in 2015, there was a 30% of its sub-district categorized in moderate to highly vulnerable to food security [3]. Even thou as a C4 crop that resistance to drought, water have becoming a major constraint to increase corn production in the semi-arid area. Nowadays, it is widely believed that to boost crop production with less water could be achieved by the increase of crop water productivity [4].

Water productivity that first introduces in 1999, with regards to physical term is defined as a unit of production per volume water use [5]. Furthermore, this notion means an enhancement of crop production with less water. This could achieve by the increase of crop production with the same unit of water use, or by production the same amount of food with less water [6]. The idea is reshaped by many studies worldwide, however, there is very limited information regarding the growth of water productivity let alone whether the growth is affected by water use efficiency or by the improvement of production technology.

Modern productivity analysis is taking into account total factor productivity (TFP) growth that also can provide information regarding the growth is predispose by efficiency growth and technology growth [7]. Malmquist index is the most popular method; the method could be calculated not only based on non-parametric approached such as data envelopment analysis (DEA) but also based on parametric approached such as stochastic frontier analysis (SFA) [8].

SFA was first proposed in 1977 either by Aigner, Lovell and Schmidts or Meeusen and van den Broeck almost at the same time. One feature of these models is that they have a composed error structure consisting of two variables: one random variable that captures noise and another one that explains technical inefficiency [9].

This study furthermore was intended to make a remarkable contribution to provide valuable information both concerning the corn water productivity by traditional subsistence farming system in the semi-arid region and the information regarding the growth with its component of efficiency and production technology. The aims of this study were to estimate corn water productivity subsequently to estimate total factor productivity growth include its components of efficiency change and technology change.

EXPERIMENTAL DETAIL

The researched was conducted in West Timor region, that part of The East Nusa Tenggara Province of Indonesia. The astronomical location was in 1230 27' 40" – 1250 11' 59" East Longitude and 080 56' 17" – 100 21' 56" South Latitude. West Timor region consists of four districts, i.e. Kupang, TTS, TTU and Belu, and a municipal, i.e. Kupang.

West Timor has the semi-arid climate that characteristic by a long dry season from April to November that inflicted by south-east monsoons from Australia, the long drought period would harm crop growth and production [10]. Furthermore, FAO stated that semi-arid area covering 40% of land worldwide and 37% inhibited land in this world. The semi-arid region features including irregular precipitation, long drought periods, evaporation rates exceeding precipitation, and steppe vegetation [11]

There were four steps in this research included firstly corn water use (CWU_{Corn}) estimate; secondly corn water productivity (WP_{Corn}) estimate; thirdly WP_{Corn} total factor productivity (TFP) growth; and the fourth was chain indices estimate. Corn water use was estimated based on the modified method from [12, 13, 14, and 15] that stated in the following formula.

$$CWU_{Corn} = HA_{corn}\left[\sum_{j\varepsilon mth} \sum_{i\varepsilon period} \min\left(Kc_{corn\ i} \times ETo_j, EFFRF_j\right) \times \frac{d_{ij}}{n_j} + \sum_{j\varepsilon mth} \sum_{i\varepsilon period}\left(Kc_{corn\text{-}i} \times ETo_j\right) \times \frac{d_{ij}}{n_j}\right] \quad (1)$$

Where, HA_{Corn} is harvested area of corn. $Kc_{corn\text{-}i}$ is crop coefficients corn. ETO_j and $EFFRF_j$ are references of evapotranspiration and effective rainfall respectively.

Corn harvested area was from the provincial statistical bureau publication [2]. Effective rainfall was estimated based on a 75 percent exceedance probability of monthly rainfall [14,15]. Reference evapotranspiration was estimated based on FAO Penman-Montieth method with the help of ETO Calculator Version 3.2 [16]. Corn coefficient was provided by the Water Resources Directorate of Indonesia. The average crop planting time was from [17]. Corn water productivity (WP_{Corn}) was calculated based on [5] that fulfill the following equation.

$$WP_{corn} = \frac{\text{Corn Production (kg kernel)}}{CWU_{Corn}(m^3)} \quad (2)$$

Total factor productivity growth of WP_{Corn} was estimated with the Stochastic Frontier Analysis – Malmquist Index (SFA-MI) method. We applied translog production function with balance panel data mean difference input; time-variant and truncated normal distribution [18]. The translog production function form was as follow.

$$\ln q_{it} = \beta_0 + \beta_1 \ln x_{it} + \beta_2 t + \beta_3\left(0{,}5 \ln x_{it}^2\right) + \beta_4 \ln x_i\, t + \beta_5\left(0{,}5\, t^2\right) + v_{it} - u_{it} \quad (3)$$

Where, q_{it} = corn production in each district each year; $x = CWU_{Corn}$; t = time (1, 2 … 16); β_0 to β_5 = model coefficients; v_{it} = random error ; and u_{it} = inefficiency effect that assumed has a truncated normal distribution.

The technical efficiency change (EFC) was calculated as a function of u_{it}. The technology change (TEC) is calculated as the geometric mean of two partial derivatives of the production function with time. TFP is widely used in productivity measurement. In the Malmquist index method, TFP is satisfying the following formula [19].

$$TFP_t = EFC_t \times TEC_t \tag{4}$$

Furthermore, in order to capture the changing of WP_{Corn} TFP change during the period of 2000 to 2015, we applied chain indices with the base period of 2000. The chain indices were estimated based on the following formula [20].

$$I_t = \left(X_t / X_{t-1} \right) I_{t-1} \tag{5}$$

Where, I_t = index at the time t, X_t = value at time t, X_{t-1} = value at time t-1, I_{t-1}= Index at time t-1

RESULT AND DISCUSSION

Corn Production

Corn harvested area in West Timor from 2000 to 2015 was fluctuated with a decreasing trend except for TTS District and TTU District. TTS district had the largest while Kupang municipal had the least corn harvested area. On the other hand, TTS district had the lowest fluctuation indicated by the coefficient of variance (CV = 16%) while Kupang municipal had a higher fluctuation (CV= 19%). Corn harvested areas in West Timor is depicted in Figure 1.

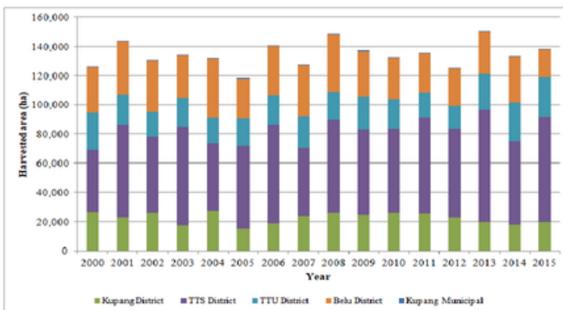

FIGURE 1. Corn harvested area in West Timor region during 2000 - 2015

To some degree as a consequence of corn harvested area fluctuation, corn production in terms of corn kernel during 2000 to 2015 fluctuated. According to [10] due to traditional farming that dominated by shifting and cultivation method in a semi arid climate like West Timor, crop production prone to natural disaster leading to crop failure as frequent as one year in five. However, farmers in TTS District and TTU district, through this period could manage to increase the production. TTS district was a leading corn producer while Kupang municipal was the least corn producer. Belu district was a second producer with highest fluctuation (CV = 29.6%) and Kupang district as the third producer had the lowest fluctuation (CV= 17%).

According to [21, 22] in anthropology perspective farmers in West Timor cultivated corn earlier than rice. Corn farmers still maintain some rituals during the cultivation process. Corn was planted in particularly areas distance from residential areas (in *Kebun*) that appointed by tribes leader. In terms of geomorphology, corn was mostly planted in dry land and hilly contour. The island of Timor also strongly affected by the El Niño Southern Oscillation (ENSO) cycle.

In the period of 2000 – 2015, West Timor farmers in average were produced 331,000 ton corn kernel annually. The maximum production was in 2013 (403.4 thousand ton) and the lowest in 2011 (254.3 thousand ton). TTS district was contributed 43.68%, Belu Districts provided 21.72%, Kupang district subscribed 16.49%, TTU district produced 14.93% and the least the Kupang municipal contribute 3.18%. Corn kernel production in 2000 – 2015 is presented in Figure 2.

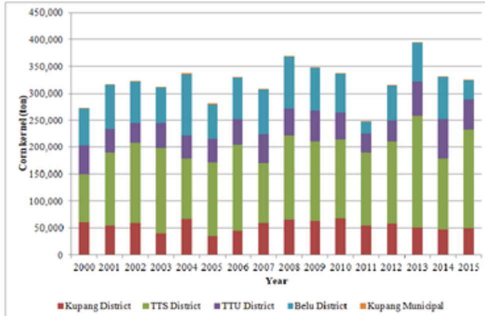

FIGURE 2. Corn kernel production in West Timor in 2000 – 2015

Corn Water Use

The main source of water for corn cultivation is from rainfall. This green water is the prominent factor for corn production in West Timor. Corn planting time was adjusted to the rainfall condition that varies from November to March each year. The peak planting season is usually in January and February when rainfall is in peak season and soil moisture is sufficient for corn seed to grow.

In the period of 2000 – 2015, corn water use (CWU_{Corn}) was fluctuation and at 2015 there were a declining in Kupang district, Belu district and Kupang municipal. Averaging water use for corn cultivation in West Timor during the period was 414.85 million m^3 per annum. Reached a peak in 2013 (545.83 Mm^3) and the lowest was in 2005 (345.91 Mm^3). TTS district utilized 45.80% followed by Belu district that used 22.91%; Kupang district used 16.84%; TTU district utilized 14.10%, and Kupang municipal used 0.34%. TTU district was more fluctuate and the least fluctuated was Kupang municipal. Corn water use (CWU_{Corn}) of West Timor region in 2000-2015 is presented in Table 1.

TABLE 1. West Timor region's Corn water use (Million m^3) during 2000 - 2015

Year	Kupang District	TTS District	TTU District	Belu District	Kupang Municipal	West Timor Region
2000	78.59	126.45	67.33	84.08	1.51	357.97
2001	69.79	188.74	51.94	108.61	1.59	420.67
2002	76.80	158.79	49.17	102.92	1.52	389.20
2003	52.81	211.48	54.02	85.81	1.55	405.67
2004	82.30	143.48	47.48	114.91	1.79	389.96
2005	44.44	176.12	47.78	75.94	1.62	345.91
2006	56.63	203.69	59.95	101.78	1.64	423.69
2007	69.93	136.13	58.24	103.36	1.35	369.01
2008	85.56	200.50	57.54	121.45	1.46	466.51
2009	69.40	169.74	54.25	90.41	1.36	385.16
2010	70.28	174.38	32.02	84.88	0.90	362.46
2011	89.81	232.61	45.43	96.48	1.08	465.41
2012	88.53	226.66	61.31	94.50	1.45	472.46
2013	70.95	283.26	90.78	99.48	1.37	545.83
2014	57.06	184.02	80.50	100.12	1.05	422.76
2015	55.09	224.22	78.16	56.17	1.21	414.85
Total	**1,117.98**	**3,040.28**	**935.91**	**1,520.91**	**22.45**	**6,637.52**
Average	**69.87**	**190.02**	**58.49**	**95.06**	**1.40**	**414.85**
Std. Deviation	**13.58**	**40.62**	**14.78**	**15.72**	**0.24**	**52.25**
Coefficient of variance (%)	**19.44**	**21.38**	**25.28**	**16.54**	**17.20**	**12.60**

Corn water use by farmers in West Timor was similar to in India and Bangladesh. The study in India reported that CWU_{Corn} reached 2,264 m^3/ha [13], while in Bangladesh it was reached 1,430 m^3/ha [23]. In West Timor, the value was 3,079.13 m^3/ha. The result revealed that there were considerable opportunities to promote water saving strategy for corn farmers in the developing world particularly in a semi-arid region like West Timor.

Corn Water Productivity

Corn water productivity (WP_{Corn}) in West Timor during 2000-2015 showed a fluctuation trend. The most fluctuated were TTU district in 2010 and Belu District in 2011. The average WP_{Corn} of West Timor was 0.782 kg kernel/m^3, the highest value was in TTU district in 2010 (1.585 kg kernel/m^3) and the lowest was in Belu district in 2011 (0.225 kg kernel/m^3). TTU district furthermore had the highest average WP_{Corn} (0.873 kg kernel/m^3); Kupang district had the average WP_{Corn} of 0.798 kg kernel/m^3) while TTS district that contributed the majority of corn production in the region had the WP_{Corn} of 0.768 kg kernel/m^3. Belu district and Kupang municipal were had the WP_{Corn} of 0.752 kg kernel/m^3 and 0.751 kg kernel/m^3 respectively.

It is interesting to note that WP_{Corn} in West Timor region was tantamount to each district regarding the great disparities in harvested area and production. This indicator expressed the efficiency and affectivity of water use to produce corn kernel. This result furthermore explained that the capacity of farmers in West Timor in using water for corn production was alike. This could be explained by the fact that in the traditional farming system, the capacity of farmers in managing water for food is similar; the slightly different was probably due to soil and topography condition, local climate, pests, and other factors. The West Timor WP_{Corn} in the last decade is depicted in Figure 3.

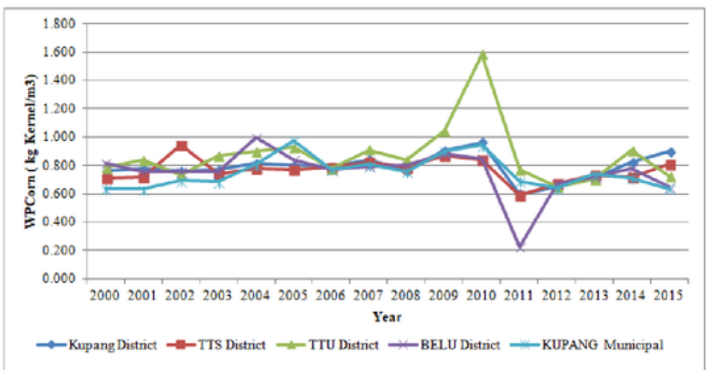

FIGURE 3. Corn Water Productivity (WP_{Corn}) of West Timor during 2000 - 2015

The value of WP_{Corn} in West Timor was in the range with what reported worldwide. The lowest value of WP_{Corn} is 0.03 kg/m^3 that cultivated in Gainesville, FL USA without irrigation and fertilizer as reported by [24]. The highest value is 7.160 kg/m^3 that cultivated in Nebraska USA with pivot irrigation system [25]. The average value of WP_{Corn} that cultivated in dry land of semi-arid region is 0,143 kg/m^3 - 1,000 kg/m^3 as reported by [26].

Corn Water Productivity Growth

The calculation of SFA-MI was with the help of FRONTIER 4.1. The Software was freely provided by the center of productivity analysis of Queensland University Australia [27]. The model coefficient of the translog production function expressed that water was a significant factor at the level of 1% in corn production. Moreover, that curvature form of water and time were also significant factors at the level of 10%. Sigma squared ($\sigma 2$) indicated total variance was lower and not significant. Gamma (γ) that indicated the ratio of inefficiency effect to total variance showed a low value and insignificant; this implied that the efficiency effect is relatively small. Mu (μ) that indicated the inefficiency effect was small and concentrated near 0. Eta (η) was negative, small and not significant indicated that inefficiency effect was narrow increase overtime but not prominent. The parameter of the estimated translog production function is reported in Table 2.

Averaging corn total water productivity (WP_{Corn} TFP) showed a decline in efficiency, technology, and total factor productivity growths. Mean efficiency and total factor productivity growth indexes were 0.996 whereas technology progress index was 1.000. Worth noting this results expressed that during the last 16 years in West Timor traditional corn cultivation system was considerable efficient in using water while production technology progress was comparatively stagnant.

TABLE 2. Stochastic frontier approximation of corn production in West Timor 2000-2015

Components	Coefficient	t-ratio
Intercept	1.48E-01	2.153**
ln CWU_{Corn}	9.55E-01	32.224***
Time	-4.47E-05	-0.006
ln CWU_{Corn}^2	-4.56E-02	-1.874*
ln CWU_{Corn} * Time	-2.59E-03	-0.975
$Time^2$	-3.99E-03	-1.729*
Sigma-squared (σ2)	5.76E-02	0.304
Gamma (γ)	4.01E-01	0.203
Mu (μ)	-1.87E-01	-0.067
Eta (η)	-1.07E-01	-0.926

Note: ***,**,and * indicated significant level at 1%, 5% and 10% respectively

The fact that traditional corn farmers relatively efficient in using water for corn production given the current technology was in some degree depart from the common perspective that traditional farmers in the semi-arid region were not efficient in using water. There is however the stagnation of corn cultivation process was apprehensible due to the limitation of farmers to gain modern technology and other production inputs. WP_{Corn} TFP growth during the period is presented in Table 3.

TABLE 3. Corn total water productivity growth of West Timor Region at 2000 - 2015

Year	Efficiency change (EFC)	Technology change (TEC)	Total factor productivity change (TFPC)
2000-2001	0.998	1.028	1.026
2001-2002	0.998	1.024	1.022
2002-2003	0.998	1.020	1.018
2003-2004	0.998	1.016	1.014
2004-2005	0.997	1.012	1.010
2005-2006	0.997	1.008	1.005
2006-2007	0.997	1.004	1.001
2007-2008	0.997	1.000	0.996
2008-2009	0.996	0.996	0.992
2009-2010	0.996	0.992	0.988
2010-2011	0.995	0.988	0.984
2011-2012	0.995	0.984	0.979
2012-2013	0.994	0.980	0.974
2013-2014	0.994	0.976	0.969
2014-2015	0.993	0.972	0.965
Mean	**0.996**	**1.000**	**0.996**

In total factor productivity (TFP) analysis, we could extract the growth components of efficiency change and technology change. TFP growth moreover could be achieved not only by the enhancement of efficiency change (catch up) but also by a positive sifting of the production frontier through the improvement of production technology [8,28]. This result exhibited that there were opportunities to upgrade water use efficiency by 3.4% at the current level of technology, likewise to advance corn production technology.

To explain the growth over time, chain indices with the base year of 2000 that had the index values of 1.000 was applied. During the period it was clear that the TFP growth was determined by the decrease of technology change rather than the slight decrease in efficiency change. There was a 0.56% reduction of efficiency change; a 5.42% reduction of technology change; that affected a 5.95% reduction of TFP. It is important to note that the growth dwindle was alarming. Nowadays, there is a continued high demanded food production due to population growth under the degradation of natural resources. So that, there should be necessary affords to tackle the downfall WP_{Com} TFP. The chain index of TFP is presented in Figure 4.

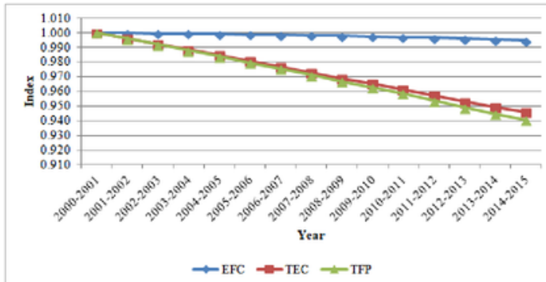

FIGURE 4. Chain indices of WP_{Com} TFP growth of West Timor during 2000 - 2015

Considering districts performance, it showed that the small producer possessed better growth. Despite TTS district and TTU district were have a better efficiency change, Kupang municipal was possessed better technology progress leading to had better TFP growth. It was understandable that as a capital city of the province, the farmers preferable to get better information and better input. Additionally, farmers in the municipal had a better socio-economy level. Districts WP_{Corn}TFP growth is depicted in Figure 5.

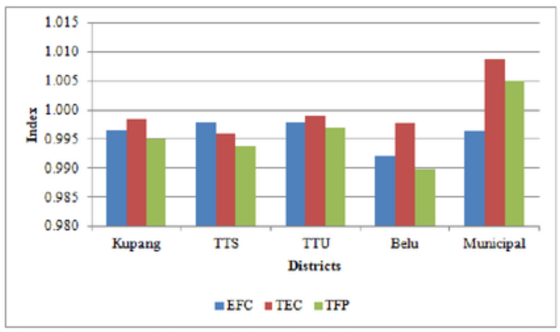

FIGURE 5. Mean Districts WP_{Com} TFP Growth during 2000 - 2015

SUMMARY

Corn as a major crop for farmers in West Timor is cultivated in traditional subsistence system. There was a fluctuation in harvested area, production and water use. Corn water use was different across time and districts. Due to the fluctuation of production and water use, corn water productivity fluctuated over time and districts. Corn water productivity value was in range with other reports worldwide, particularly in the semi-arid region. Stochastic translog production function explained that water in terms of volumetric water use was the notable factor. Besides that water and time were have a quadratic influence over corn production. With regard to corn total water productivity growth, in average farmers in the region were considerable efficient in used water for corn production but the technology did not progress. During the period all the productivity measures namely efficiency change, technology change, and total factor productivity change were subsided. The degradation of technological change more steep than of efficiency, therefore the technology change determined the TFP growth. Considering food security, there should be an advance in corn water use efficiency and production technology. With regard to the performance of the districts, it exhibited the growth regardless the scale of production but rather the quality of the process. Besides environment and climate, other elements influenced the water productivity growth such as access to better information, technology, production inputs, and farmers' socio-economy conditions.

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