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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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International Conference on Biology and Applied Science

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Abstract Book

"BIODIVERSITY AND ENVIRONMENT IN 4IR: ISSUES, PARADIGM AND REALITY"

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In Collaboration Between:

Welcome Speech

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Chairman's Speech

Dear distinguished guests, respected colleagues, ladies, and gentlemen,

Firstly, it is a great honor for me to welcome all of you to Malang. On behalf of the organizers of the 1st International Conference on International Conference on Biology and Applied Sciences (ICOBAS) 2019, I would like to express my deepest gratitude for your presence in this opening ceremony as the gateway to initiation to our scientific program.
In particular, I would like to extend my gratitude to distinguished guests both keynote and invited speakers. Please allow me to express my sincere appreciation for coming to our campus for:

1. Prof. Dr. Tatsuya Ueki, Mukaishima Marine Biological Laboratory, Graduate School of Science, Hiroshima University, Japan
2. Prof. Dr. Toshifumi Sakaguchi (Department of Life Science, Prefectural University of Hiroshima (PUH), Japan)
3. Prof. Dr. Noppadon Kitana (Department of Biology, Chulalongkorn University, Thailand)
4. Dr.Panupong Thammachoti (Department of Biology, Chulalongkorn University, Thailand)
5. Prof. Akira Kikuchi (Faculty of Agriculture, University of Brawijaya, Malang, Indonesia)
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Secondly, the idea of International Conference on Biology and Applied Science (ICOBAS) 2019 originated predominantly from Congres of Indonesian Society for Biology XIV and Biology National Conference XX which has been conducted on 2009 at Department of Biology, Faculty of Science and Technology, State Islamic University of Malang, Indonesia. In this event, at least more than 600 of Indonesian's researchers/lecturers attended and presented their papers, as well all participants committed to strengthen conservation effort of Indonesian biodiversities for sustainable use of today and future generation. Ten years laters, we concerntly focus to discuss several issues dealing with biodiversity concervation in 4 industrial revolution era. Thus, the objectives of the ICOBAS conference is to provide a scientific forum to contribute to biodiversity conservation and environmental protection especially in this 4 industrial revolution era. In this forum, the scientist could share their knowledge and explore the opportunities for international collaboration from a range of disciplines in order to sustain our biosfer.

Even this conference is officially the first conference held by our department, but it got much attention from researchers, lecturers and students from over Indonesian and also foreign country. We recorded that 365 abstracts were registered in our conference website, but we accepted only 285 abstracts to be presented in this meeting.

Finally, it is our pleasant duty to acknowledge our collaborators, Mukaishima Marine Laboratroy, Graduate School of Science, Hiroshima University, Prefectural University of Hiroshima (PUH), Japan, Chulalongkorn University, Thailand, Society for Biology Lecturer of Islamic University, Biology Consortium of Indonesia (KOBI), State University of Malang, as well as our financial support, PT New Module International.

We hope all participants will enjoy this conference and also Malang City, as well make a special relationship with Malang.

Sincerely,

Didik Wahyudi
Chairman of ICOBAS 2019

International Conference on Biology and Applied Science

Secretariat: Department of Biology, Faculty of Science and Technology
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ICOBAS Meeting Schedule

20 – 21 March 2019
Hotel Sahid Montana 2, Malang, East Jave, Indonesia

Day I, 20 March 2019

Time	Program	Venue	PIC
07.00 – 08.00	Registration	Lobby	Committee
08.00 – 08.30	**Opening ceremony**		MC
08:00 – 08.05	Recitation of Holy Quran		Rifky Wahyudi
08.05 – 08.10	National Anthem: Indonesia Raya		Fitriyah, M.Si1
08.10 – 08.17	Conference Report by Chairman: Mr. Didik Wahyudi	Wijaya Kusuma Hall Room	
08.17 – 08.25	Opening Speech by Dean of Faculty of Science and Technology UIN Malang or representative		
08.25 – 08.30	Recitation of Du'a		Mujahidin Ahmad, M.Sc
08.30 – 08.45	Coffee break		Committee
08.45 – 09.35	**Plenary Lecture I** *Mechanism of Vanadium Accumulation and Possible Function of Vanadium in Underwater Adhesion in Ascidians* (Prof. Tatsuya Ueki, Mukaishima Marine Lab. Hiroshima Univ., Japan) *Possibility of Bioproduction of Semi-conductive Material by Marine Bacteria* (Prof. Toshifumi Sakaguchi, Department of Life Science, Prefectural Univ. of Hiroshima, Japan)	Wijaya Kusuma Hall Room	Dr. Romaidi
09.35 – 10.25	**Plenary Lecture II** *Vertebrate and Invertebrate Species as Sentinels for Herbicide Contamination in Paddy Fields* (Prof. Dr. Noppadon Kitana, Department of Biology, Chulalongkorn University, Thailand) *Taxonomic Revision and Distribution of Scincid Lizards in Highland of Java and*	Wijaya Kusuma Hall Room	Berry Fakhry Hanifa, M.Sc

In Collaboration Between:

	Sumatra (Dr.Panupong Thammachoti' Department of Biology, Chulalongkorn University, Thailand)		
10.25 – 11.25	Poster session		Committee
11.25 – 12.25	Ishoma/Lunch Break		Committee
12.25 -12.40	**Invited Speaker I:** *Biodiversity pattern Encoding and Decoding between Species and Community Level via Fourier Transformation* (Prof. Akira Kikuchi, Faculty of Agriculture, Univ. of Brawijaya)	Wijaya Kusuma Hall Room	Berry Fakhry Hanifa, M.Sc
12.25 -12.40	**Invited Speaker II:** *Beneficial Roles of Trichoderma in Agriculture: a Study in Leguminous Plants* (Eriyanto Yusnawan, Ph.D, Balitkabi, Malang))	Teratai Room	Prilya Dewi Fitriasari, M.Sc
12.25 -12.40	**Invited Speaker III:** *Histological Profile of Small Intestine and Kidney Rats (Rattus norvegicus) Infected by Salmonella typhi after Giving Earthworm Flour* (Dr. Bayyinatul Muchtaromah, M.Si (UIN Malang)	Anggrek Room	Dr. Kiptiyah, M.Si
12.25 -12.40	**Invited Speaker IV:** *Enhancing Early Stage of Hepatocellular Carcinoma: Does Correlate to MicroRNA 122a and miR196a interaction?* (Hendra Susanto, Ph.D, University of Malang)	Alamanda Room	Mujahidin Ahmad, M.Sc
12.45 – 13.45	Parallel session I (6 rooms)		All
13.45 – 14.45	Parallel session II (6 rooms)		All
14.45 – 15.00	Coffee break		Committee
15.00 – 16.00	Parallel session III (6 rooms)		All
16.00 – 17.00	Parallel session IV (6 rooms)		All

Day II, 21 March 2019

Time	Program	Venue	PIC
08.00 – 09.00	Parallel session V (6 rooms)	All rooms	All
09.00 – 10.00	Parallel session VI (6 rooms)		All
10.00 – 11.00	Parallel session VII (6 rooms)		All
11.00 – 11.30	Closing Ceremony		MC
11.30 – 12.30	Lunch break		Committee

In Collaboration Between:

HIROSHIMA UNIVERSITY

県立広島大学
Prefectural University of Hiroshima

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

Topic : Plant Biodiversity/Botany
Room : Teratai Room
Day/Time : I / 15.00 – 16.00
Moderator : Dr. Evika Sandi Savitri, M.P/ Azizatur Rahmah, M.Sc

MN	**Author**	**Title**
93 ✓	Jonathan E. Koehuan, Bambang Suharto, Gunomo Djoyowasito, and Liliya D. Susanawati	Corn Water Productivity growth using Stochastic Frontier Analysis – Malmquist Index (A case of West Timor – Indonesia)
94	Haerul Annas, Nunik Cokrowati, and Muhammad Marzuki	*Gracilaria verrucosa* growth rate cultivated using bottom off method
96	Hamidah, Mety Mi'rojiah Nindy Astuti, and Rosmanida	Diversity of Rambutan Fruit Variety (*Nephelium lappaceum* L.) Through The Morphological Approach
100	Muhammad Rizza Pahlevi, Serafinah Indriyani, Retno Mastuti, and Estri Laras Arumingtyas	The wilting and death response of *Capsicum frutescens* L. in flooding stress
110	Novi Haryati and Apichaya Lilavalicakhul	Can Small and Medium Entreprise Survive MEA 2025? A Case Study On Soybean Chips Enterprise In Malang, Indonesia

Topic : Plant Biodiversity/Botany
Room : Teratai Room
Day/Time : I / 16.00 – 17.00
Moderator : Dr. Evika Sandi Savitri, M.P/ Azizatur Rahmah, M.Sc

MN	Author	Title
118	Susi Rahmawati, U. E. Hernawan and A. Rustam	The Seagrass Carbon Content of 0.336 of Dry Weight Can be Applied in Indonesian Seagrasses
128	Aeng Saputra, Anggraeni, Nur Azizah, and Sembi Peringati	The Pteridophyta Diversity In Jerieng Menduyung Nature Tourism Park, West Bangka
149	Eko Sri Sulasmi, Suhadi, Murni Sapta Sari, and Kuni Mawaddah	Identification of Alkaloids Components from the Fronds of 5 Species Pterydophyta in Baluran Nasional Park
173	Hamidah, Thin Soedarti, and Mulyadi Tanjung	Relationship Analysis of the genus Annona with the RAPD Approach
177	Hartati Kartikaningsih, Yahya, Sri Dayuti, Agus Tumulyadi, and Rifqi Saiqul Umam	Characteristics Brown Seaweed Tea Sargassum cristaefolium From Talango Island, Madura, East Java

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

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Abstract. Corn is one of the most popular crop worldwide includes for the West Timor farmers. However, there is 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 (Corn WP) of West Timor subsequently to determine its total factor productivity (TFP) growth during 2000-2015. To doing so, we used 16 years balanced panel data of climate and cropping data. Corn WP was estimated based on crop water use (CWU). Then SFA-MI was applied to determine TFP growth. The results showed that mean corn WP 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 districts (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 0f 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 increase the water efficiency to boost and sustain corn production.

Keywords: corn, growth, water productivity, TFP, water use

In Collaboration Between:

Corn water productivity growth of West Timor, Indonesia

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Corn Water Productivity Growth of West Timor, Indonesia

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Abstract. Corn is one of the most popular crops worldwide, including West Timor farmers. However, minimal reports on corn water productivity (WP_{Corn}) growth exist. This research would make a remarkable contribution to fill this gap. This study aims to estimate WP_{Corn} of West Timor to subsequently determine its total factor productivity (TFP) growth during 2000–2015. To do so, we used 16 years of balanced panel data on climate and the crop. 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 being 1.585 kg/m^3 in the TTU district (2010), while the lowest was 0.225 kg/m^3 in the Belu district (2012). Average TFP growth was 0.996, equal with efficiency change (EFC) and technology change (TEC), which was 1.000. However, during this period, there were decreases in TFP, EFC, and TEC by 5.949%, 0.557%, and 5.422%, respectively. The 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 uses 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 an increase in corn production of 1% per year, during 2003 and 2013, there was a reduction in corn household 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%), using less chemical fertilizer (15%), using low pest control (23%), and doing manual and self-harvesting (98%) and mostly for household consumption (87%). As a consequence of the farming system, corn production is prone to natural hazards, such as high intensities 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. However, based on world food assessments in 2015, 30% of its sub-districts were categorized as having moderate to high vulnerability to food security [3]. Although corn is a C4 crop that is resistant to drought, the water became a major constraint to increase corn production in the semi-arid area. Today, it is widely believed that boosting crop production with less water could be achieved through an increase in crop water productivity [4].

Water productivity was first introduced in 1999, with regards to the physical term 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 through an increase 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 has been reshaped by several studies worldwide; however,

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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 takes into account total factor productivity (TFP) growth, which can also provide information regarding whether the growth is predisposed by efficiency growth and technology growth [7]. The Malmquist index is the most popular method; the method can be calculated not only based on a non-parametric approach, such as data envelopment analysis (DEA), but also based on a parametric approach, such as stochastic frontier analysis (SFA) [8]. SFA was first proposed in 1977, either by Aigner, Lovell and Schmidt, or Meeusen and van den Broeck, almost 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 that explains technical inefficiency [9].

Furthermore, this study intends to make a remarkable contribution by providing valuable information, both concerning corn water productivity (WP_{Corn}) by traditional subsistence farming systems in semi-arid regions and information regarding growth with the component of efficiency and production technology. This study aimed to estimate WP_{Corn} to subsequently estimate TFP growth, including its components of efficiency change and technology change.

EXPERIMENTAL DETAILS

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

West Timor has a semi-arid climate that is characterized by a long dry season from April to November that inflicts monsoons from Australia in the southeast. The long drought period harms crop growth and production [10]. Furthermore, FAO stated that semi-arid areas cover 40% of land worldwide and 37% of inhibited in this world. The semi-arid region features include irregular precipitation, long drought periods, evaporation rates exceeding precipitation, and steppe vegetation [11].

There were four steps in this research: first, a corn water use (CWU_{Corn}) estimate; secondly, a corn water productivity (WP_{Corn}) estimate; thirdly, WP_{Corn} total factor productivity (TFP) growth; and fourthly, a chain indices estimate. CWU_{Corn} was estimated based on the modified method from [12, 13, 14, and 15], which is stated in the equation 1:

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

where HA_{Corn} is the harvested area of corn, Kc_{corn-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 corn data was from the provincial statistical bureau publication [2]. Effective rainfall was estimated based on a 75% 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 corn coefficient was provided by the Water Resources Directorate of Indonesia. The average crop planting time was from [17]. WP_{Corn} was calculated based on [5], which fulfil the equation 2.

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

Total factor productivity growth of WP_{Corn} was estimated 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:

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

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 assumed to have a truncated normal distribution.

The technical efficiency change (EFC) was calculated as a function of u_{it}. The technology change (TEC) 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 with the following formula (equation 4) [19].

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

Furthermore, to capture the WP_{Corn} TFP change during the period of 2000–2015, we applied chain indices with a base period of 2000. The chain indices were estimated based on the following formula (equation 5)[20].

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

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

RESULT AND DISCUSSION

Corn Production

The corn harvested area in West Timor from 2000–2015 fluctuated with a decreasing trend, except for the TTS district and the TTU district. 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 higher fluctuation (CV= 19%). The corn harvested areas in West Timor are depicted in Fig. 1.

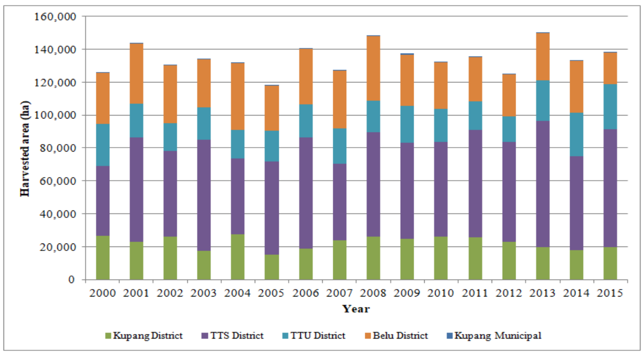

FIGURE 1. Corn harvested area in West Timor region during 2000–2015

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

Farmers in West Timor cultivated corn earlier than rice (from an anthropological perspective) [21-22]. Corn farmers still maintain some rituals during the cultivation process. Corn was planted particularly in areas distant from residences (in *Kebun*) that were appointed by tribal 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.

Between 2000–2015, West Timor farmers, on average, were producing 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 contributed 43.68%, the Belu district provided 21.72%, the Kupang district subscribed 16.49%, the TTU district produced 14.93% and, the lowest producer, the Kupang municipal contributed 3.18%. Corn kernel production in 2000–2015 is presented in Fig. 2.

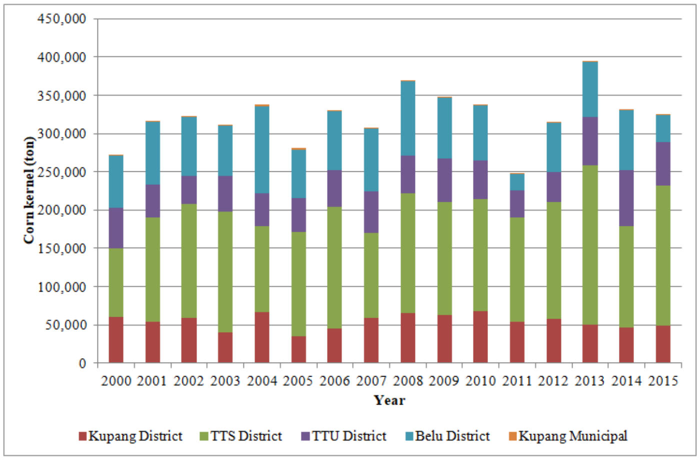

FIGURE 2. Corn kernel production in West Timor in 2000–2015

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 at its peak season, and soil moisture is sufficient for corn seed to grow.

In the period of 2000–2015, CWU_{Corn} fluctuated, and in 2015, there was a decline in the Kupang district, the Belu district, and the Kupang municipal. Average water use for corn cultivation in West Timor during this period was 414.85 million m^3 per annum. It reached 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 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 fluctuated more, and the least fluctuating was the Kupang municipal. CWU_{Corn} of the 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**

CWU_{Corn} by farmers in West Timor was similar to that in India and Bangladesh. A study in India reported that CWU_{Corn} reached 2,264 m^3/ha [13], while in Bangladesh, it 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 significant opportunities to promote water-saving strategies for corn farmers in the developing world, particularly in semi-arid regions such as West Timor.

Corn Water Productivity

WP_{Corn} in West Timor during 2000–2015 showed a fluctuation trend. The most fluctuating was the TTU district in 2010 and the Belu district 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 an average WP_{Corn} of 0.798 kg kernel/m^3), while the TTS district, which contributed the majority of corn production in the region, had a WP_{Corn} of 0.768 kg kernel/m^3. The Belu district and the Kupang municipal had 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 effectivity of water used to produce a 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 slight difference was probably due to soil and topography condition, local climate, pests, and other factors. West Timor WP_{Corn} in the last decade is depicted in Fig. 3.

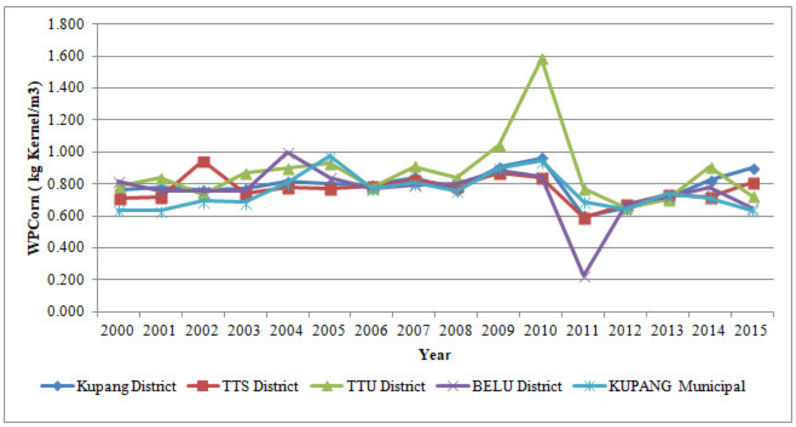

FIGURE 3. Corn water productivity (WP_{Corn}) of West Timor during 2000–2015

The value of WP_{Corn} in West Timor was in the range of what was reported worldwide. The lowest value of WP_{Corn} was 0.03 kg/m^3, cultivated in Gainesville, FL, US, without irrigation and fertilizer, as reported by [24]. The highest value was 7.160 kg/m^3, cultivated in Nebraska, US, with a pivot irrigation system [25]. The average value of WP_{Corn} that was cultivated in dry lands of semi-arid regions 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 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, this curvature form of water and time was also a significant factor at the level of 10%. Sigma squared ($\sigma 2$) indicated total variance was lower and not significant. Gamma (γ), which indicated the ratio of inefficiency effect to the total variance, showed a low value and was insignificant; this implied that the efficiency effect is relatively small. Mu (μ) indicated that the inefficiency effect was small and concentrated near 0. Eta (η) was negative, small, and not significant, indicating that the inefficiency effect was narrow, with increase over time, but was not prominent. The parameter of the estimated translog production function is reported in Table 2.

Average 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 is that the results expressed that during the last 16 years in West

Timor, the traditional corn cultivation system was considerably 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 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, in some degree, departed from the common perspective that traditional farmers in the semi-arid region were not efficient in using water. 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 this period is presented in Table 3.

TABLE 3. Corn total water productivity growth of the West Timor region 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 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 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 base year of 2000 that had the index value of 1.000 was applied. During the period, it was clear that the TFP growth was determined by the decrease in technology change, rather than the slight decrease in efficiency change. There was a 0.56% reduction in efficiency change and a 5.42% reduction in technology change, which resulted in a 5.95% reduction in TFP. It is important to note that the growth dwindle alarming. Today, there is a continued high demand for food production due to population growth under the degradation of natural resources. Thus, there should be necessary affords to tackle the downfall WP_{Corn} TFP. The chained index of TFP is presented in Fig. 4.

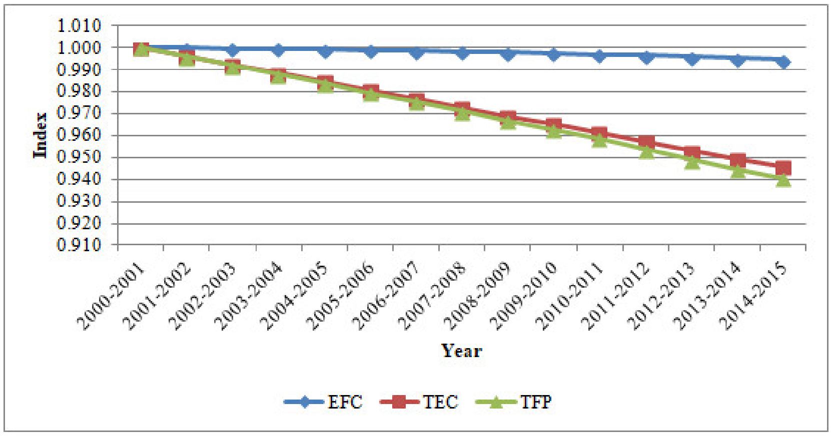

FIGURE 4. Chain indices of WP_{Corn} TFP growth of West Timor during 2000–2015

The districts' performance showed that the smaller producer possessed better growth. Despite the TTS district and the TTU district having better efficiency change, the Kupang municipal possessed better technology progress, leading to better TFP growth. It was understandable that as a capital city of the province, the farmers preferred to obtain better information and better input. Additionally, farmers in the municipal had better socioeconomic status. The districts' WP_{Corn}TFP growth is depicted in Fig. 5.

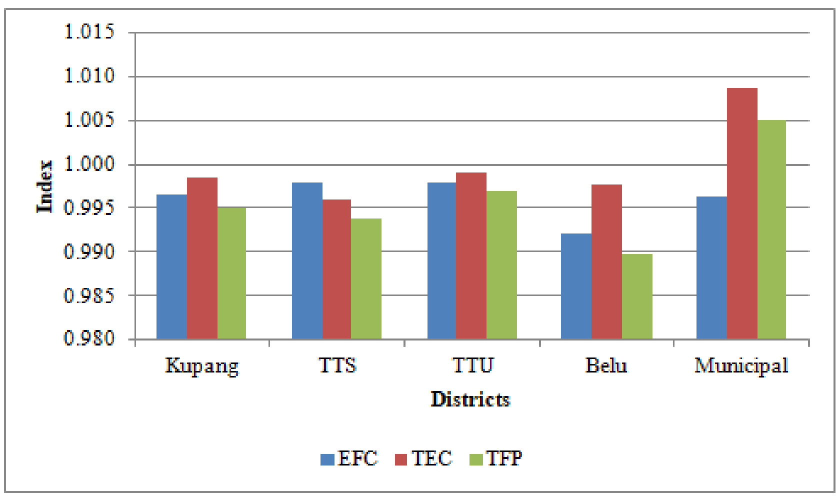

FIGURE 5. Mean districts' WP_{Corn} TFP growth during 2000–2015

SUMMARY

Corn, as a major crop for farmers in West Timor, is cultivated through the traditional subsistence system. There was a fluctuation in harvested area, production, and water use. Corn water use differed across time and districts. Due to the fluctuation in production and water use, corn water productivity fluctuated over time and districts. The corn water productivity value was in range with other reports worldwide, particularly in semi-arid regions. Stochastic translog production function explained that water, in terms of volumetric water use, was the notable factor. Water and time had a quadratic influence over corn production. With regard to corn total water productivity growth, on average, farmers in the region were considerably 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, subsided. The degradation in technological change was steeper than that of efficiency; therefore, the technology change determined 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, they exhibited growth, regardless of the scale of production but, rather, the quality of the process. Besides the environment and climate, other elements influenced water productivity growth, such as access to better information, technology, production inputs, and farmers' socioeconomic conditions.

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