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Evaluating Impact of Land Use Changes and Climate Variability on Economic Efficiency of Farming in Transboundary Watershed of Timor Island

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Abstract

Indonesia and Timor-Leste development of border regions in Timor Island has brought land use changes, and when combined with climate variability it may cause flooding, drought, and impact of economic efficiency of farm crop. The research aimed to analyze: (i) the effect of land use changes and climate variability on the floods and drought on the Tono Watershed, (ii) the impact of flood, drought and production factors in yield and the economic efficiency of food crop farming. The analysis applied logit method for flood and drought. Frontier analysis to evaluate economic efficiency of farming. Logit analysis showed that the increase in the monthly rainfall and mix dryland farming, along with the decrease of forestry and paddy fields increase the flooding on Tono Watershed. The result further suggested by this analysis showed drought has caused by the increase of mix dryland farming and monthly temperature, and decrease of monthly rainfall. This led to a reduction in yield and economic efficiency of farm crops. Frontier analysis confirms the low economic efficiency of farming, whereas monoculture farming was 0.36 (affected by floods and drought) and multicrop farming was 0.30 (affected by drought) which is far from the efficiency standard ≥0.8.

Keywords: land use change; climate variability; flood and drought; economic efficiency of farming; Indonesia and Timor-Leste transboundary watershed

1. Introduction

The Tono Watershed is one of the watersheds in the border that is beneficial to the farming activities of the communities in the border of Indonesia and Timor-Leste, especially enclave district of Timor-Leste. Both Indonesia and Timor-Leste development in the border regions have conversion, conservation area to cultivation area. This was resulting flood and drought on Tono Watershed. Todaro and Smith (2002) state, regional development is the process of improving the quality of life, whereas it inevitably has an impact on population growth and land conversion.

These changes are representative of a broader movement of unused land to farm land due to population pressure. The change of covered shrub land into agricultural land resulted in the higher run-off of water and increased erosion. This reduces the resilience of the land to cope with variations in weather, higher and lower than average rainfall. Combined with the increasing climate variability leaves the surrounding area vulnerable to flooding and drought. Hoanh *et al*. (2004) suggested that climate change had a significant impact on farm production, especially for low income farmers who depended on subsistence farming.

The proximate cause of flooding is monthly rainfall, and the proximate cause of drought is monthly rainfall and temperature. The accumulation of effective rainfall in the upstream area of the Citarum watershed over four consecutive days led to flooding in 2000-2009 (Dasanto *et al*., 2014). Average yearly rainfall on Tono Watershed from 2000 to 2014 fluctuated (Fig. 1). Rainfall was lowest from 2002 to 2005 and also dropped from 2012-2014, while in 2000-2001 and 2007-2011 the average rainfall was relatively high. Rainfall was lowest from 2002 to

2005 and also dropped from 2012-2014, while in 2000-2001 and 2007-2011 the average rainfall was relatively high. Fluctuation in monthly rainfall indicated a modest climate change, according to the type of climate changes as referred by Schneider and Sarukhan in UNDP (2004).

Climate variability and land use change on Tono Watershed is contributing greatly to the agricultural sector. There are 54.94% land use on Tono watershed dominated by agriculture (dryland, mix dryland, and paddy fields) which is planting crops. It is experienced by surrounding farmers and excess water (flood), normal rainfall, and insufficient water (drought) on the farm. Farming activities on Tono Watershed can be categorized into dryland farming and wetland farming. Dryland farming in the area is normally practiced with a ‘slash-burn’ land clearing system, followed by multicropping agriculture. Wetland farming typically uses monoculture crop rotations. Farming production on Tono watershed uses production factors such as land, labour, seed, fertilizer inputs, equipment, technology, and cropping pattern. Climate variability has also been described as a production factor, and in this analysis is categorized as being characterised by rainfall as flood, normal, or drought. The increased of flood frequency, flood level, duration and flood incidence lowered production and the value of agricultural products, especially in the downstream (Klein *et al*., 2004).

It was important to conduct the research of climate variability effects on Tono Watershed. Therefore, the objectives of this research were to analyze (i) the effects of land use changes and climate variability on the probability of flooding and drought the Tono Watershed, (ii) the impacts of flood, drought and production factors that could be controlled by farmers related to yield and economic efficiency (EE) of multicrop and monoculture of farming on Tono Watershed.

2. Materials and Methods

2.1 Data

Location of research on Tono Watershed, Timor Island, borderland of Indonesia and Timor-Leste (Fig. 1). Identification of land use changes and climate variability used secondary data with a time series of 15 years, from 2000 to 2014. The data of rainfall were from CHIRPS (http://chg-ftpout.geog.ucsb.edu/puborg/chg/products/CHIRPS-2.0/global-monthly/tifs/), and the data of temperature were from CRU (http://iridl.ldeo.columbia.edu/SOURCES/.UEA/.CRU/.TS3p0/). Data average rainfall on Tono Watershed in 2000 to 2014 are shown in Fig. 2. The land use data were derived from Landsat. Data of the land use changes on Tono Watershed in 2000 and 2014 are shown in Table 1.

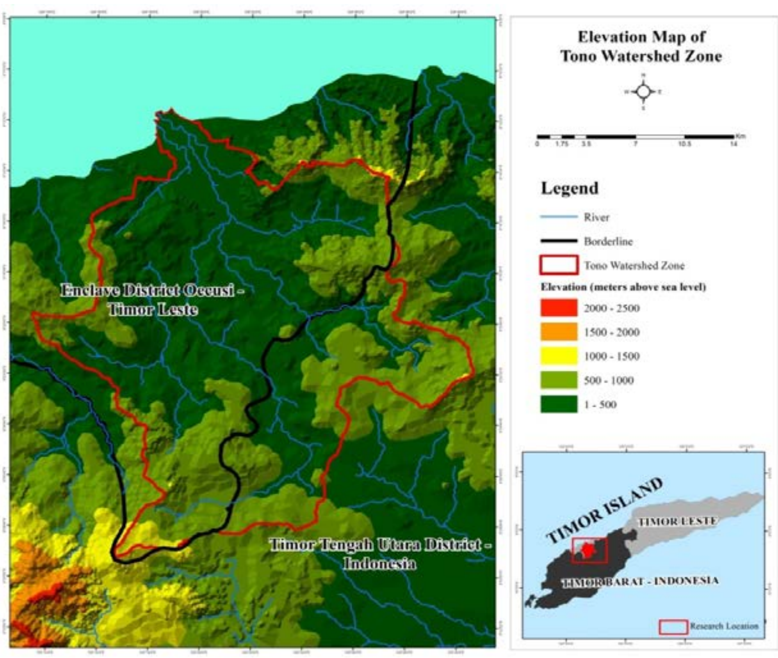

Figure 1. Area of study

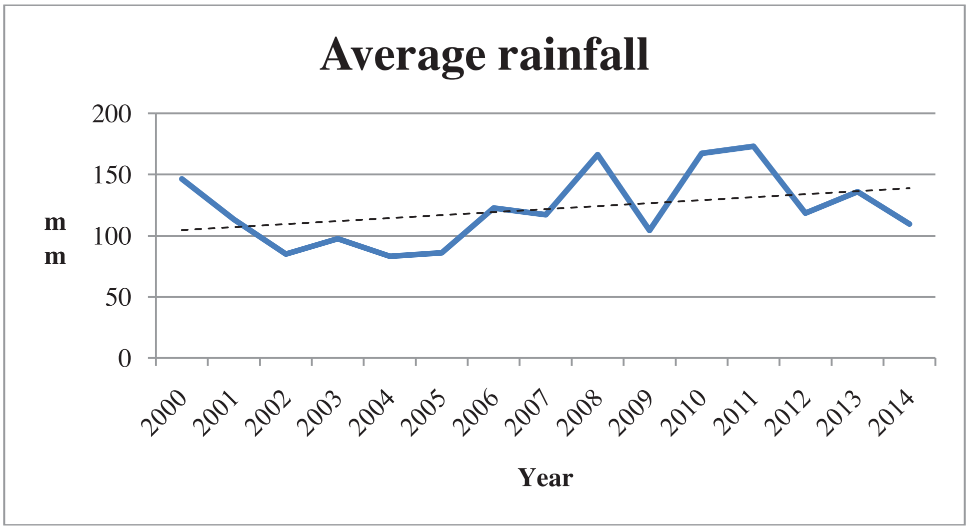

Figure 2. Variability of rainfall on Tono Watershed in 2000 - 2014

The research also used primary data to collect floods, drought and variable of economic efficiency of farming (input, yield, and prices of input and yield). Technical sampling used purposive sampling. The number of monoculture farmer samples were 50 respondents (10 Indonesians and 40 Timorese), and multicrop farmer samples were 95 respondents (60 Indonesians and 35 Timorese).

2.2 Method of analysis

This analysis consisted of two steps which written out from the flowchart (Fig. 3). The first step was to evaluate the impact of land use changes and climate variability to floods and drought on Tono Watershed. The assessment of flood and drought by using logit function (modified from Pradhan, 2009) as follows:

$$P(x_t) = \frac{1}{1+e^{-(\alpha+\beta x_t)}} = \frac{e^{(\alpha+\beta x_t)}}{1+e^{(\alpha+\beta x_t)}} \qquad (1)$$

$$\text{Ln}\,(Px_t) = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \varepsilon$$

Description:

$Px_t/1\text{-}Px_t$: ratio between the probability of monthly flood and no flood on Tono Watershed in year t (0 = no flood; 1 = flood)

X_{1t} : Average monthly rainfall in year t on Tono Watershed (mm)

X_{2t} : Size of mix dryland farming in year t on the Tono Watershed (ha)

X_{3t} : Size of forestry in year t on Tono Watershed (ha)

X_{4t} : Size of paddy fields in year t on Tono Watershed (ha)

X_{5t} : Size of savanna in year t on Tono Watershed (ha)

α : intercept

$\beta 1 \ldots \beta i$: Coefficient of independent variable

Table 1. The land use changes on Tono watershed in 2000 and 2014

Land Use	2000 (ha)	2014 (ha)	Change	
			(ha)	(%)
Secondary dryland forest	703	675	28	3.98
Open land	1,045	1,095	-50	-4.78
Settlement	262	550	-288	-109.92
Dryland farming	2,842	5,383	-2,541	-89.41
Mixed dryland farming	17,102	22,662	-5,560	-32.51
Savanna	7,235	6,368	867	11.98
Paddy fields	937	1,327	-390	-41.62
Shrub	21,571	13,651	7,920	36.72
Shrub and swamp	48	40	8	16.67
Body of water	1,719	1,713	6	0.35
Total	53,464	53,464	0	0

Source: Processed data of landsat, 2010 and 2014

Analysis by Equation (1) with different variable was also used to show the probability of drought occurrence on Tono Watershed. Independent variables consist of: monthly temperature (^{o}C), monthly rainfall (mm), and size of mix dry land farming (ha).

The second step was to assess the impact of flood and drought on yield and EE of the farming system. The impact of flood and drought on yield was estimated using multivariate regression for multicrop farming, and multiple regression for monoculture farming. Multivariate regression analysis as follows:

$$LnY_{nq} = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \delta_1 D_{pt} + \delta_2 D_b + \delta_3 D_k + \varepsilon..... \quad (2)$$

Description:

Y_{nq} : yields q (paddy, corn, peanuts) of multicroping farming n
X_{1i} : size of land (are)
X_{2i} : labor (man day)
D_{pti} : dummy multicropping pattern 1 = 3 food crops and, 0 ≠ 3 food crops
D_{bi} : dummy flood 1 = flood, 0 = normal
D_{ki} : dummy drought 1 = drought, 0 = normal
β_0 : intercept
β_i, δ_i : regression coefficient εi: error

Analysis with Equation (2) with different variable was also used to show the yield of monoculture farming. There is one dependent variable of farming, i.e. paddy. Independent variables consist of: size of land, seed, fertilizer, labour, dummy flood, dummy drought.

Further, EE was estimated using Cobb Douglass stochastic profit function (modified from Masuku, 2014), which is combining the concepts of technical efficiency (TE) and allocative efficiency (AE) in profit relationship. So, the profit function was chosen over production function because multicroping farming, and the production function requires that TE and AE be regressed separately in order to estimate EE, while the profit function just analysis EE directly. The two stage approach of analyzing EE as follows:

(i) the study assumed that the profit of farming was dependent on land rent, seed cost, fertilizer cost, labour cost, tractor rent, dummy multicropping (Dp), dummy flood (Db), dummy drought (Dk), dummy state (Dn). The profit function are regressed using Cobb Douglass function as follows:

$$LnY_i = \beta_0 + (\beta_1 \textstyle\sum_{i=1}^{n} lnX_1) + \beta_2 lnX_2 + \delta_1 D_{pt} + \delta_2 D_b + \delta_3 D_k + \varepsilon \quad (3)$$

(ii) efficiency scores are derived:

$$EEi = \frac{\Pi_i}{\Pi^*_i} \quad (4)$$

Description:

EEi : economic efficiency of farming i
Πi : profit farming i
Π*i : maximum profit farming i

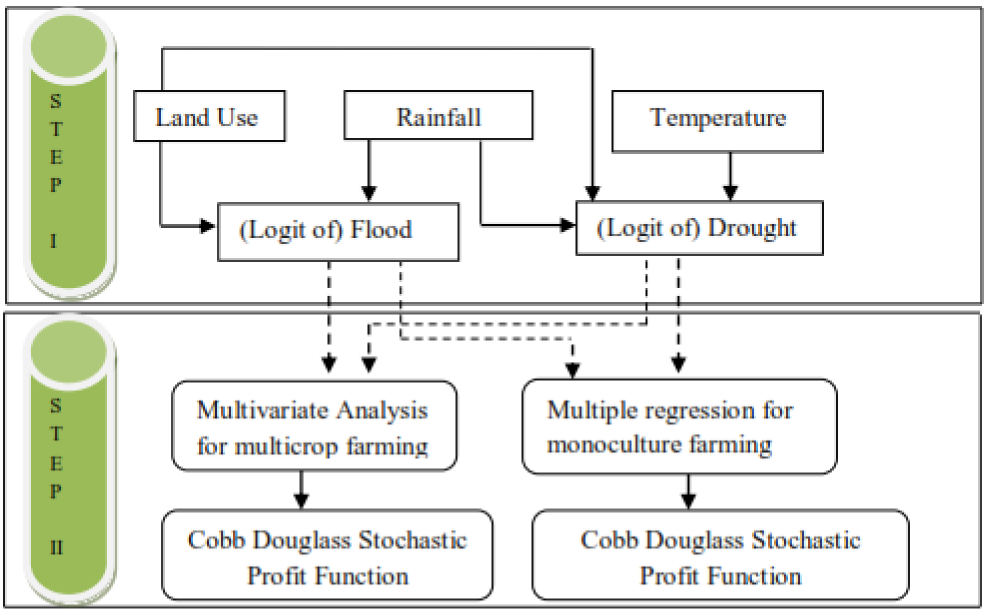

Figure 3. The flowchart of techniques analysis

3. Results and Discussion

3.1 Land use changes and climate variability on Tono watershed

3.1.1 Land use chages on Tono watershed

An analysis using GIS, as in Fig. 4 explains that the land use on Tono Watershed has been most conversions from schrubland to dryland and the mixdryland farming. The observation that I have done before, showed that the shrubland was characterised by permanent plants and long roots, while dryland and mixed dryland farming characterised periodically by slush-burn. These land use changes in the upstream areas impact on the upstream, midstream and downstream areas of Tono Watershed, because it affects the movement of soil and water over the whole watershed. As Klein *et al*. (2004) reported, flooding in the upstream area of the watershed has a considerable impact on the downstream area.

The upstream area of Tono Watershed represented 72%, midstream 17%, and downstream 11%. Land use change in the upstream areas saw, notably, a more than doubling in dryland farming from 1,700 ha to 4,102 ha and a huge increase in mixed dryland farming from 10,697 ha to 15,799 ha; representing conversion of nearly 20% of total land area in the upstream area over just 15 years. This was mostly accounted for by conversion of shrubland. The midstream area also underwent extensive conversion of shrub land to dryland and mixed dryland farming, evidenced at 27% decrease in shrubland. The downstream area also underwent at 21% reduction in shrubland. The model of land use, which can referral policy making of the land use on Tono Watershed is the Nankan Watershed (Yu *et al.,* 2003) that developed a model of sustainable land use in the Nankan watershed integrating human activity, land resources, and water resources.

The conversion of shrubland to dryland and mixed dryland farming remains the most important trend, but a country breakdown shows that the conversion of shrubland is significantly more severe in Indonesia, where shrubland reduced by nearly 50%, whereas in Timor-Leste this reduction was closer to 25%. This trend was reflected in the increased use of land for agriculture, where dryland and mixed dryland farming in Indonesia increased from less than 1% of total land in 2000 up to 42% of land in 2014, while in Timor-Leste this increase was from 48% to 56%. Land conversion is driven by socio-economic changes (Herold *et al*., 2006) which are influenced by government policy, NGO activity and broader social changes. Decision makers in Indonesia and Timor-Leste could exercise control by implementing an alternative modification for land use. It is necessary for conducted joint management to reduce the risk of flood events (Snelder, 2008), and include revitalization traditional farming (Mwaura *et al*., 2015).

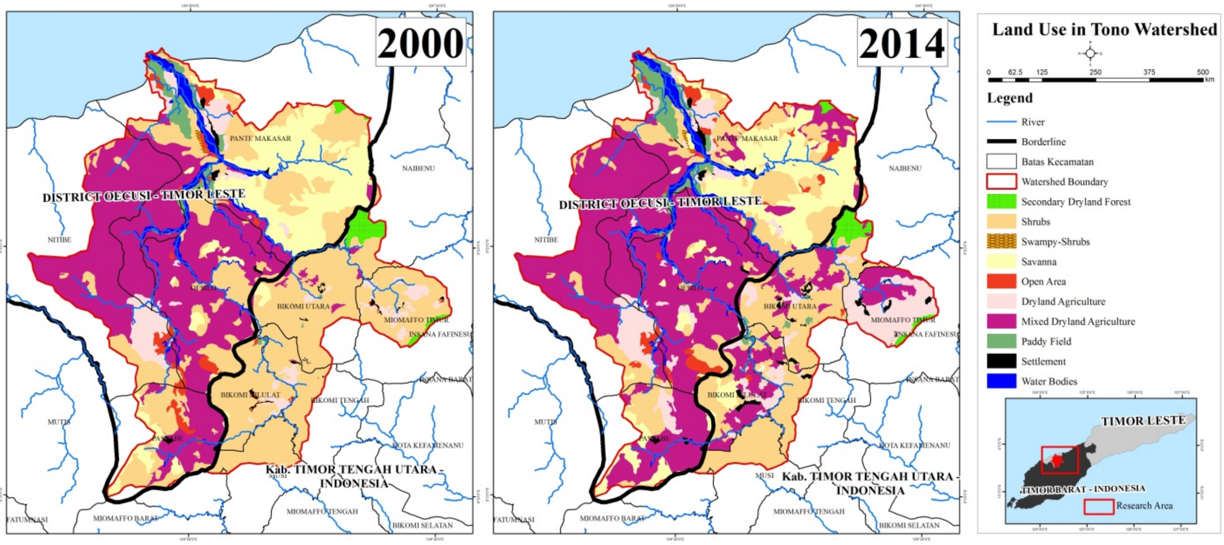

Figure 4. Land use changes on Tono watershed in 2000 and 2014

3.1.2 Climate variability on Tono watershed

Representation of climate variability can be observed from the changes of climate elements, such as rainfall and temperature. The differences of rainfall between Indonesia and Timor-Leste on Tono Watershed (Fig. 5) show that the rainfall in Indonesia was almost always higher than in Timor-Leste. As stated by Kundzewicz *et al*. (2014) that there were strong variations in rainfall in the regions and between regions. It's caused by the differences of geography, based on my observation, this distinction because scattered in different watershed zones. The different of rainfall between upstream, midstream, and downstream on Tono Watershed (Fig. 6) show that yearly rainfall (average from monthly rainfall) on the upstream and midstream areas were almost always higher than the downstream area. The variation of temperature on Tono Watershed about 23.4^{O}C to 27.6^{O}C.

3.2 The effect of land use changes and climate variability on the probability of flood and drought occurrence

The logit analysis results showed the variables in the model collectively affected the probability of flood on Tono watershed, as similarly as the probability of drought. Partially, the factors that had a significant effect of flood was the monthly rainfall, the increase in mixed dryland farming, and decrease of forestry and paddy fields area as a representation of social and economic activities contributed to the floods on Tono Watershed. As stated by Bronstert (2003), and accumulated of rainfall would increase the volume of run-off that caused floods (Roy *et al.,* 2001). The result further suggested by this analysis showed drought has caused by increase of mixed dryland agriculture and monthly temperature, and decrease of monthly rainfall. The result of logit analysis shown in Table 5.

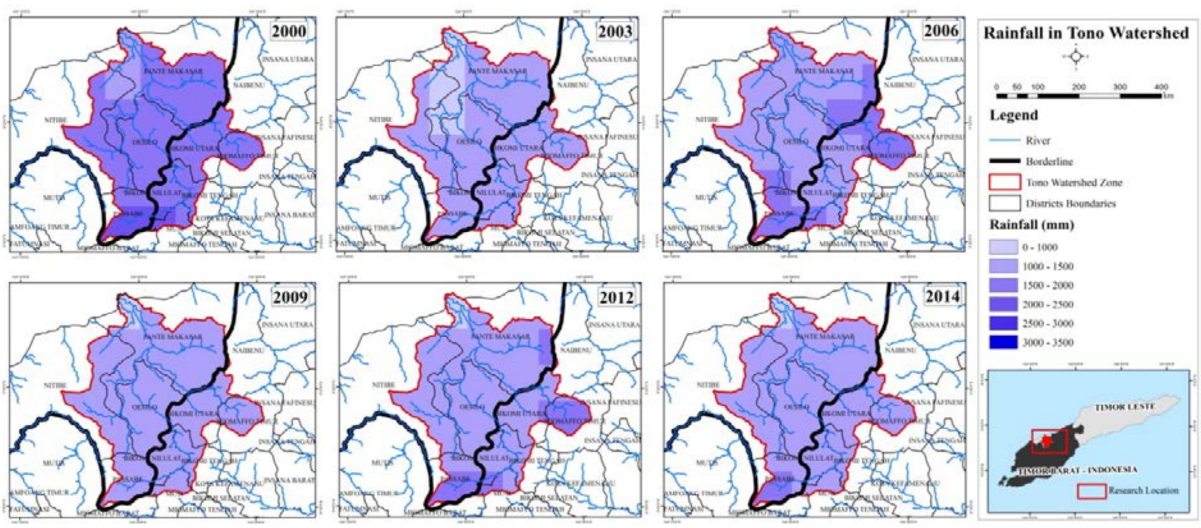

Figure 5. Rainfall on Tono watershed in 2000-2012 based on the teritorial region of watershed (Source: CHIRPS)

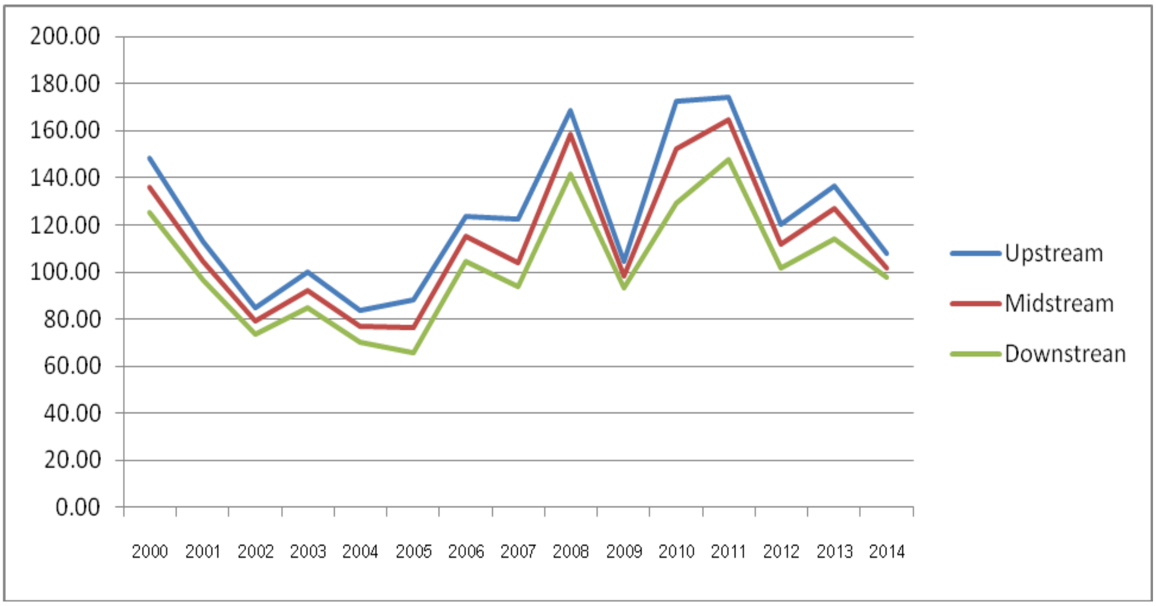

Figure 6. Rainfall on Tono watershed in 2000-2014 based on watershed zones (Source: CHRIPS)

Mixed dryland agriculture is a conversion of shrubs (Figs. 4 and 7) that had land cover which is functioning as land conservation. Based on the result in my model and the observation, these changes, has caused flooding and drought on Tono Watershed. In this area, extensification of wetland reducing the incidence of flooding due to the conversion of open land (Fig. 6). This externality can be coped with policies, one of it stated by Snelder (2008) that to improve the river with a combination of hydraulic functions such as land use: agricultural, natural, recreational and residential areas; rather than by strictly separating the affected part of the river flood.

Both Indonesia and Timor-Leste governments can perform partial processing through the control of farming dryland by slash-and-burn, with sedentary cultivation in the garden with intercropping plantation crops, fodder and food crops. Integrated management can be carried out between the governments of Indonesia and Timor-Leste to establish transboundary watershed management institutions. Faced the situation, we can refers to the research who found that transboundary watershed management is important to reduce the negative externality (Lautze and Giordano, 2005; Wondwosen, 2008; Mumme, 2010; Mckee, 2010).

Table 5. Results of logit analysis of the effects of land use changes and climate variability on probability of flood and drought on Tono Watershed

Logit Flood		Logit Drought	
Variable	Coefficient	Variable	Coefficient
Intercept	170.7650	Intercept	-35.8485
Rainfall	0.0182***	Temperature	1.3408***
Mixed dryland agriculture	0.0011**	Rainfall	-0.0162***
Forest	-0.2506**	Mixed dryland agriculture	0.0001*
Paddy fields	-0.0209**	G-test of flood: 98.44***	
Savanna	-0.0003	G-test of drought: 72.34***	

Note: *significant α = 0.10, **significant α = 0.05 and ***significant a α = 0.01

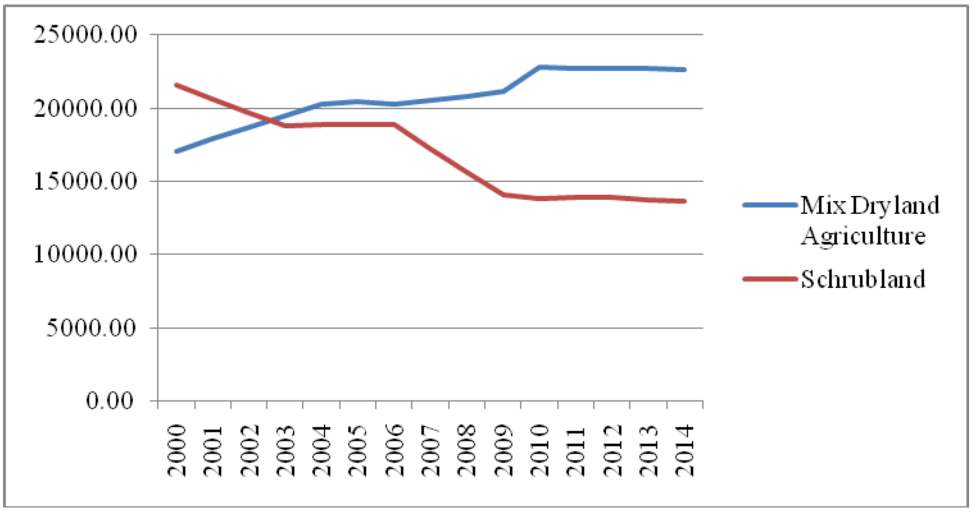

Figure 7. Land use changes from schrubland to mix dryland agriculture

3.3 *Impact of flood, drought and production factors on yield and economic efficiency of farming on Tono watershed*

3.3.1 Yield of multicrop and monoculture farming

Floods and droughts risk on Tono Watershed generally to agricultural land, there are 54.94% land use on Tono Watershed dominated by agriculture (dryland, mix dryland, and paddy fields) which is planting crops. Dryland farming applies a slash-burn system using an intercropping pattern. Food crops are intercropping with different combinations such as rice, corn, cassava, sweet potatoes, peanuts, green beans. Multivariate analysis showed that the drought reduces production of paddy and corn, while multiple regression showed that the flood and drought reduce paddy production. The optimum use of water increased the production of rice, wheat, potatoes in the watershed, so proper irrigation is very important (Morid *et al.*, 2004). Impact measurement of flood, drought and other input to yield of multicrop farming and monoculture farming shown in Table 6.

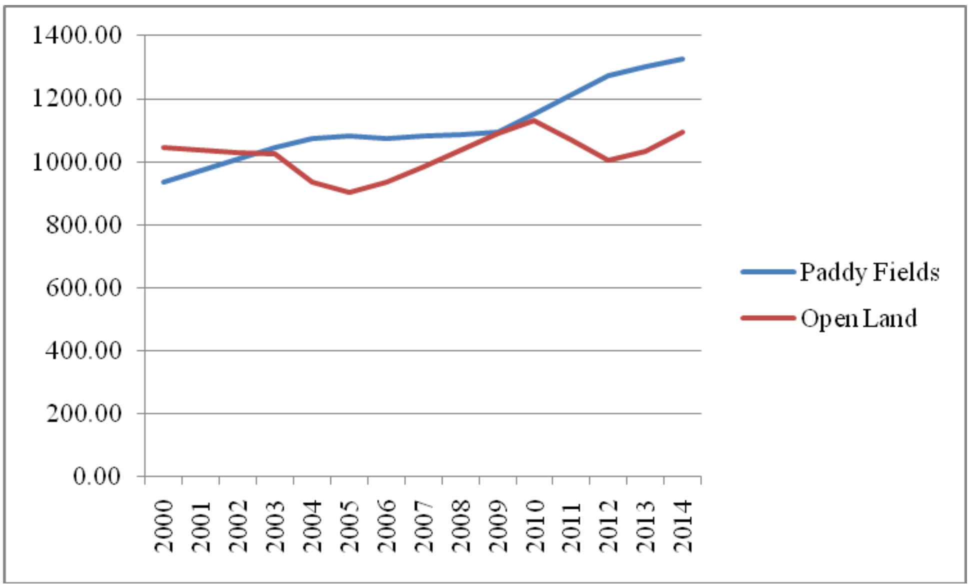

Figure 8. Land use changes from open land to paddy fields

Table 6. Regressed multivariate for multicrop farming and multiple for monoculture farming

Input	Multicrop			Input	Monoculture
	Paddy	Corn	Peanuts		
Intercept	5.63	2.87	4.95	Intercept	3.44
Size of land	0.11	0.35***	-0.01	Seed	0.34*
Labour	0.19	0.30***	0.13	Fertilizer	0.39***
Dpt	0.18	0.32***	0.26*	Labour	0.31*
Db	0.02	-0.22	-0.10	Db	-0.78**
Dk	-0.59***	-0.60***	-0.22	Dk	-0.80***
R^2	36.16	60.11	17.92	R^2	67.10

Note: *significant α = 0.10, **significant α = 0.05 and ***significant a α = 0.01

3.3.2 Economic Efficiency (EE) of farming analysis

The results of frontier analysis showed that the average value of the EE of multicrop farming was 0.30 (range from 0.10 to 0.81) and monoculture farming was 0.36 (range from 0.23 to 0.67). Coelli *et al*. (1998) reported that EE between 0 and 1, and ≥ 0.8 was efficient. It means dryland farming and wetland farming on boundary watershed is not efficient. The average value for EE of farming was low because its vulnerability to water availability (drought and flood). The increase in temperature would increase water use and reduce the growth and agricultural production (Droogers *et al*., 2004). As Warren *et al*. (2006) stated that agricultural sector has a very high dependency on the climate; every 3°C increase in air temperature led to starvation for about 600 million people, particularly in developing countries where there is a risk of food shortages. Klein *et al*. (2004) reported that an increased frequency of flood, the level and intensity of flood led to an decrease in production and value of agricultural products.

Adaptation of flood and drought can be done with use of fertilizers in farming dryland (due to the current dryland farming does not use fertilizer), and increased use of fertilizers in farming wetland (α = 0.01). The low production and farming efficiency was also related to mastery level of agricultural technology and low access to markets (Schneider and Gugerty, 2011). Farming efficiency can be improved by use of an appropriate technology (Trewavas, 2001). Another technology that began in Indonesia on dryland farming was terracing, and combinations of food crops with crops longevity (α = 0.10). Minh and Long (2009) stated that full economic efficiency would reduce the cost of agricultural production up to 46 percent. Therefore, it requires institution of transboundary watershed management (Wondwosen, 2008) and sustainable ecosystem-based adaptation as presented by Mc Evoy *et al*., (2008).

4. Conclusions

Based on the results and discussion, it can be concluded land use changes and climate variability occurred on Tono Watershed. Most of the change was conversion of shrubland to dryland and mixed dryland agricultural. This caused flooding (in January to March) and drought (in April and May) on Tono Watershed. Extensification of wetland reducing the incidence of flooding due to the conversion of open land, beside that. the diversion of the flow of water through irrigation decreases it. Frontier analysis confirms the low economic efficiency of farming, whereas wetland farming was 0.36 (affected by floods and drought) and dryland farming was 0.30 (affected by drought) which is far from the efficiency standard ≥ 0.8. Therefore, should be looking forward necessary institutional transboundary watershed management of Indonesia and Timor-Leste on the Timor Island.

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