Development strategies of agricultural sector toward environmental externalities: case study in East Java, Indonesia

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Abstract. This research was conducted to measure the agricultural sector's externalities and to generate a model of proper strategies to encourage sustainable economic development through the agricultural sector. This research employed time-series data of 1987-2016 periods at selected province in Indonesia (East Java). Agricultural sector's externalities were addressed by environmental degradation variables (greenhouse gas emissions) and environmental carrying capacity variable. The 2006 IPCC guidelines for green house gas inventories tier 1 and land balance approach was utilized to calculate those externalities. Furthermore, for generating a model of proper strategies, the second law of thermodynamics was applied through a simultaneous equation model that was analyzed with Two-Stage Least Square method. This research revealed that agricultural income, environmental degradation, and environmental capacity have simultaneously significant interrelationship. Intensifying credit allocation for rural farm household and adding direct investment in the agriculture sector can decrease environmental degradation, escalate environmental carrying capacity, and increase agricultural income.

1. Introduction

Along with developing civilization, the 2nd Thermodynamics Law point of view provided awareness that every effort to fulfill human's needs, by natural resources utilization in industry, agriculture, fishery, services, and so on, would not get 100% of efficiency. It means that every benefit and effect yielded by the utilization is not only perceived by the subjects of the economic activities solely but also come into other parties outside of the activities, such as environment and society who utilize environmental services [1]. According to the opinion, every economic activity does not only yield economic value but also generates externalities that can be a benefit or negative effect on the whole societies.

Growing population demands highly increasing food production in order to ensure food availability and food security. Intensive farm management, which is employed by many agricultural practitioners allows high natural resources exploitation. This fact has been postulated by Kuznets, who identified the relationship between various indicators of environmental degradation and economic growth, well-known as the environmental Kuznets curve (EKC). EKC describes that in the early stages of growing economic process, environmental degradation (pollution) increase. Furthermore, the trend will reverse and indicate high-income economic growth generates environmental improvement [2].

Nowadays, approximately 1 billion people in developing countries (Sub-Saharan Africa and Asia) are undernourished. It was predicted that one person in twenty will still be undernourished by 2050

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although agricultural production doubles. This production growth would indicate agriculture remaining vital sector of economic development, environmental services, and rural poverty eradication [3]. Thus, sustaining resources to retain the ability for providing sufficient food is the central part of agricultural development [4].

Agricultural development policies have been successful at emphasizing external inputs as the significant part to increase food production. This has produced high growth in global consumption of inorganic fertilizers, pesticides, tractors, animal feed, and other machinery. These external inputs have replaced natural balance process and resources, delivering them more vulnerable [5]. Moreover, the current universal agriculture system cannot achieve an important objective. That is meeting the needs of the present without compromising the ability of future generations to meet their own needs. Modern agriculture system implemented by most of the farmers drives to lead environmental degradation and turns the earth system beyond the 'safe operating space' for humanity. However, agriculture will still play a pivotal role in maintaining environmental services, which can be yielded by its activities.

Many researchers have examined and measured the value of environmental externalities of the economic activities [6–10]. The critical point to do it was the decision to limiting various externalities to get specific proper variable. Two main negative externalities of agricultural activities are represented by greenhouse gases emissions. In 2007, the Intergovernmental Panel on Climate Change (IPCC) published the fourth report that apparently indicated the primary determinant of global climate warming. Above 90% of global climate change is generated by mankind's activities. Regarding the report, agricultural activities play a role in contributing to greenhouse gases emissions, thus on climate change [11]. Several types of research in the past time revealed that greenhouse gases emissions have a relationship with agricultural economic growth [12, 13].

Beside agricultural activity generates negative externalities, it generates positive externality also, which is formed of environmental carrying capacity. The previous study stated that mankind's need for environmental resources could be declared as the width of the area which is needed for supporting mankind's life. This indicator is defined as an ecological footprint. Moreover, their report explained that determining natural and environmental resources sustainability level could be calculated by comparing finger footprint to the size of the actual production area. Thus, agricultural cultivation could be the leading party for increasing environmental carrying capacity[14].

Indonesia earns a pivotal role in the agricultural sector in its economy. The agricultural sector is the most significant source of employment in which around 40.12 million people are employed, equal to 33% of the whole labor force. Moreover, the agricultural sector still contributes to 14% of the Gross Domestic Product (GDP) in 2014. Although playing a significant role in Indonesia's macroeconomic, it still cannot afford the significant level of poverty alleviation. Poverty in Indonesia is still dominated by the rural and agricultural region, where over 60% of the miserable life [15].

Indonesia has the opportunity to maintain agricultural sector as a vital part in its development agenda since it has 55 million ha of agricultural land and 129 million ha of forest, besides prominent agricultural labor force [16]. Being the fourth of the most populous countries provide a large number of the food market, but this could be challenging while population growth leads to a significant number of land pressure, food demand, and high input exploitation [15].

We selected East Java as representative of this research. East Java is the most populated province and one of the most vital provinces for Indonesia's economic development. Supported by its infrastructure and local resources, economic development in this region has good progress at an economical value side. That economic value is manifested in Regional Gross Domestic Product (RGDP) value and employment. Based on Statistical Agency, in 2013, East Java has yield Rp. 1,136,326.87 billion, and it was equal to 14,99% of Indonesia GDP. At the same time, employment in this province was 19.081.995 employees, and this number is the most significant employment in Indonesia [16]. This significant role in Indonesia's economy, it has shown that East Java has become a pioneer in economic success at the macroeconomic side. One thing that has to be realized, the success of macroeconomic can't be the primary indicator that economic development will sustain in the long term. In fact, the agricultural sector has a significant role in employment and RGDP of East Java. In

2013, 40.41% of all employees worked in this sector. Meanwhile, only 13.83% RGDP of East Java was created by this sector [16].

A significant role of the agricultural sector in the economy has to be a consideration for the farmer and other stakeholders. The agricultural sector creates externalities, which may be negative or positive. The other important thing which has to be a consideration for the long-term economic development is the environmental degradation caused by negative externalities of the agricultural sector. Degradation or decreasing of environment quality is decreasing environment ability to provide environmental services and goods for a human being. According to that definition, if the agricultural sector were managed unwisely now, agricultural sector performance, even the whole regional economic, will be declined in the future.

Based on this background, this research was conducted to provide an appropriate approach to facing environmental externality yielded by the agricultural sector. The appropriate approach could generate raw-model of proper strategies to encourage sustainable economic development through the agricultural sector for many emerging-economic and developing countries which have many challenges in environmental issues and deal with constraints in employing their resources. Moreover, the strategies have to be able to increase agricultural production, increase positive environmental externality, and decrease negative externality.

2. Materials and Method

2.1. Location and Data

The research location was selected by purposive method considering local condition. Employment, Long-Term Development Plan, and agricultural RGDP were the reason for selecting East Java as a research location.

Type of data used in this research was secondary data. Data was collected from agencies that provide suitable data for this research. This research employed time-series data of 1987-2016 periods

2.2. Data analysis method

Environmental externalities in this study are represented by two indicators, namely greenhouse gas emissions and environmental carrying capacity generated by agricultural activities. Greenhouse gas emissions denote negative externalities, while environmental carrying capacity implies positive externalities. Both indicators are combined with the actual economic value variables of the agricultural sector in the analysis model.

2.2.1. Measurement of Green House Gases (GHG) of Agricultural Sector

Measurement of GHG emission in agricultural activity was based on the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines. This study accommodates four sources of agricultural greenhouse gas emissions, including enteric fermentation of livestock, livestock manure, application of urea fertilizer, and rice cultivation.

An approximate number of CH_4 emission from livestock enteric fermentation was measured with the formulation as:

$$Es = EF_T \times N_T \times 10^{-3} \quad (1)$$

where:

Es = total methane emissions from livestock enteric fermentation, (ton/year)
$EF_{(T)}$ = emission factor for the defined livestock population, (kg CH_4/head/year)
$N_{(T)}$ = the number of head of livestock species/category T (head)
T = species / category of livestock

An approximate number of CH_4 emission from manure management was measured with the formulation as this:

$$CH_4\, Manure = \sum_T \frac{(EF_T * N_T)}{10^3} \quad (2)$$

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where:

CH_4 *Manure* = CH_4 emissions from manure management (ton/year)

EF_T = emission factor for the defined livestock population, (kg CH_4/unit/year)

N_T = the number of head of livestock species / category T (head)

T = Species / category of livestock

The basic equation to estimate CH4 emissions from rice cultivation are estimated by multiplying daily emission factors by cultivation period of rice and annually harvested areas. In its purest form, this equation is implemented using national activity data (i.e., national average cultivation period of rice and area harvested) and a single emission factor.

$$RE_{CH4} = L_t \times H_t \times EF_{rf} \times 10^{-3} \tag{3}$$

where:

RE_{CH4} = methane emissions from rice cultivation (ton/year)

L_t = harvested area of rice (ha)

H_t = cultivation period of rice (200 days).

EF_{rf} = a daily CH_4 emission factor of rice (0,14 kg CH_4/ha/day)

The approximate number of CO_2emission from urea application was measured by the following formula:

$$CO_2UREA = M_{urea} \times EF_{urea} \tag{4}$$

where :

CO_2UREA = annual CO_2 emissions from urea application (ton/year)

M_{Urea} = annual amount of urea fertilization (ton/year)

EF_{Urea} = urea emission factor ton CO_2 per unit of urea. (Default IPCC Apply an overall emission factor (EF) of 0.20 for urea, which is equivalent to the carbon content of urea on an atomic weight basis (20% for $CO(NH_2)$)).

2.2.2. Environmental Carrying Capacity Measurement

Environmental carrying capacity measurement of the agricultural sector was estimated by the Indonesian Ministry of Environment Rule Number 17 2009 approach [17]. This approach utilized the ratio of potential land supply and land demand, which generated by agricultural activities. Furthermore, measurement of environmental carrying capacity was formulated as:

1. Land Supply:

$$S_L = \frac{\sum(P_i \times H_i)}{H_b} \times \frac{1}{Ptvb} \tag{5}$$

where:

S_L = land supply (ha)

P_i = actual production of all agricultural commodities

H_i = Price of each agricultural commodity (Rp/unit)

H_b = Price of rice (Rp/kg)

$Ptvb$ = rice productivity in one ha rice field (kg/ha)

2. Land Demand:

$$D_L = N \times KHL_L \tag{6}$$

where:

D_L = land demand (ha)

N = the number of population (head)

KHL_L = Expediency of sufficient ned (assumed equal to 1 ton of rice)

Environmental carrying capacity value (CC) is a comparison ratio of land supply (S_L) to land demand (D_L). If $CC > 1$, it means that environmental carrying capacity is categorized in surplus status (high). If $CC < 1$, it means that environmental carrying capacity is categorized in deficit status (low).

2.2.3. Simultaneous Equation Analysis Model

Based on the theory and a review of several kinds of literature, such as those already reconciled in Chapter 1, we can note the relationship between production activities and environmental externalities. Production activities in the agricultural sector not only produce economic value from the main products but also produce externalities related to environmental services. In the next stage, the performance of agricultural production will be affected by the consequences of the reciprocal process. In this study, we are using simultaneous equations. A study stated that where simultaneity exists, use of ordinary least squares to approximate single equation relationships might give a biased and erroneous estimate [2]. In order to approximate the strong environment-income relationship, it is, therefore, more appropriate to employ a simultaneous equation model. [18], however, noted that because of the difficulty in model specification and getting the needed data, the simultaneous relationship between economic growth and environmental quality had not been employed by any empirical studies. Three structural equations are used in the model in this study by testing three endogenous variables, namely agricultural RGDP, environmental degradation, and environmental carrying capacity in East Java Province. These structural equations are formulated as follows:

1. Structural equation of environmental degradation

$$DG_t = \rho_0 + \rho_1 PRC_t + \rho_2 PJG_t + \rho_3 PUKY_t + \rho_4 PUJ_t + \rho_5 PKD_t + \rho_6 LAND_t + \rho_7 RPOV_t + \gamma_1 YAGR_t + \rho_8 D_1 + U_1 \quad (7)$$

where:

DG = environmental degradation (ton CO_2)
PPADI = rice productivity (ton/ha)
PJG = maize productivity (ton/ha)
PUKY = cassava productivity (ton/ha)
PUJ = sweet potatoes productivity (ton/ha)
PKD = soybean productivity (ton/ha)
YAGR = agricultural RDGP (IDR)
LAND = farmland width (Ha)
RPOV = rural poverty rate (%)
D_1 = *Dummy* Long Term Development Plan of East Java Province 2006-2025 (1 if t ≥ 2006, 0 if < 2006)
U_1 = disturbance
Ρ = exogenous variable coefficient
Γ = endogenous variable coefficient
T = year t

2. Structural equation of environmental carrying capacity

$$CC_t = \delta_0 + \delta_1 DEN_t + \delta_2 LAB_t + \delta_3 LAND_t + \delta_4 D_1 + \gamma_2 YAGR_t + U_2 \quad (8)$$

Where:

CC = environmental carrying capacity
YAGR = agricultural RGDP (IDR)
DEN = population density (head/km^2)
LAB = the number of agricultural labor (head)
LAND = farmland width (ha)
D_1 = *Dummy* Long-Term Development Plan of East Java Province 2006-2025 (1 if t ≥ 2006, 0 if < 2006)
U_2 = disturbance
Δ = exogenous variable coefficient
Γ = endogenous variable coefficient
T = year t

3. Structural equation of agricultural RGDP

$$YAGR_t = \beta_0 + \beta_1 CRD_t + \beta_2 LAB_t + \beta_3 INV_t + \beta_4 LAND_t + \beta_5 POP_t + \beta_6 RPOV_t + \beta_7 D_1 + \gamma_4 CC_t + \gamma_5 DG_t + U_3 \quad (9)$$

Where:

YAGR	= agricultural RGDP (IDR)
CC	= environmental carrying capacity
CRD	= credit allocated to the agricultural sector (IDR)
LAB	= the number of agricultural labor (head)
DG	= environmental degradation (ton CO_2)
INV	= investment value of agricultural, chemistry, and timber industry (IDR)
LAND	= farmland width (Ha)
RPOV	= rural poverty rate(%)
POP	= population (head)
D_1	= *Dummy* Long Term Development Plan of East Java Province 2006-2025 (1 if t ≥ 2006, 0 if < 2006)
U_3	= disturbance
Β	= exogenous variable coefficient
Γ	= endogenous variable coefficient
T	= year t

3. Result and Discussion

3.1. Environmental Degradation: GHG Emissions of Agricultural Sector

Table 1 shows that all components of the environmental degradation of the agricultural sector in East Java Province increased in 1987-2016 periods. CH_4 from poultry manure growth rate is the biggest; it's 7.82% per year. It gives the implication that increasing performance in husbandry sub-sector, especially poultry commodity, is followed by increasing GHG emissions. Even though CH_4 from poultry manure growth rate is the biggest; it isn't the most dominant emission component produced by the agricultural sector. Rice cultivation is the most dominant component which produces GHG of the agricultural sector in East Java.

Table. 1. Approximate environmental degradation of the agricultural sector in East Java province.

GHG Emissions	Average Value 1987-2016 (ton/yr)	Growth Rate 1987-2016 (%/yr)
CH_4 from livestock enteric fermentation	187.910,94	0,89
CH_4 from livestock manure	9.725,52	2,24
CH_4 from poultry manure	3.038,65	7,82
CO_2 urea application	216.901,90	0,76
CH_4 rice cultivation	472.070,37	1,69

Source: Data analysis, 2019.

3.2. Simultaneous Analysis Model of Environmental Degradation, Environmental Carrying Capacity, and Agricultural RGDP in East Java Province

We used *E-views 9* software to analyze the simultaneous model by Two-Stage Least Square (TSLS) analysis result of environmental carrying capacity equation is shown in Table 2. TSLS analysis yields F-probability as 0,000002, and this result shows that at α=0,01, simultaneously, agricultural RGDP, population density, farmland width, the number of agricultural labor, dummy East Java Province Long Term Development Plan 2006-2025 are significant determinants of environmental carrying capacity. Based on the partial test (t-test), we know that agricultural RGDP and farmland width are positively significant determinants of environmental carrying capacity. It means that if agricultural RGDP or farmland width increase, *ceteris paribus*, environmental carrying capacity will increase too. This condition is appropriate with the hypotheses expected by this research.

Table 2. TSLS analysis result of environmental carrying capacity

Variable	Coefficients	Probability	F-probability	Adjusted-R^2
C	0,330058	0,6617		
YAGR	2,69.10^{-14}	0,0020**		
DEN	-0,002652	0,0824*		
LAND	3,45.10^{-7}	0,0112**	0,000002***	0,8614
LAB	6,49.10^{-8}	0,2258		
D1	0,059824	0,3931		

= Significant at α=0,1; **= Significant at α=0,05; *= Significant at α=0,01*
Source: Data analysis, 2019.

Two-Stage Least Square (TSLS) analysis result of environmental degradation equation is shown in Table 3. TSLS analysis yields F-probability as 0,077756, and this result shows that at α=0,01, simultaneously, agricultural RGDP, rice productivity, maize productivity, cassava productivity, sweet potatoes productivity, soybean productivity, farmland width, rural poverty rate, and dummy East Java Province Long Term Development Plan 2006-2025 are significant determinants of environmental degradation. Based on the partial test (t-test), we know that maize productivity and sweet potatoes productivity are negatively significant determinants of environmental degradation. It means that if maize productivity or sweet potatoes productivity increase, *ceteris paribus*, environmental degradation will decrease. This condition is contrary to the hypotheses expected by this research.

Table 3. TSLS analysis result of environmental degradation

Variable	Coefficients	Probability	*F-probability*	Adjusted-R^2
C	-7,17. 10^{13}	0,1240		
YAGR	-0.806848	0,5112		
PJG	-1,63. 10^{13}	0,0950*		
PUKY	4,49. 10^{12}	0,0129**		
PKD	2,72. 10^{13}	0,2832		
PPADI	1,15. 10^{13}	0,1508	0,077756*	0,4210
PUJ	-1,96. 10^{12}	0,0057**		
RPOV	-3,93. 10^{11}	0,3111		
LAND	16727814	0,1939		
D1	4,13. 10^{12}	0,4451		

**= Significant at α=0,1; **= Significant at α=0,05*
Source: Secondary Data Analysis, 2019.

Moreover, Two-Stage Least Square (TSLS) analysis result of agricultural RGDP equation is shown in Table 5. TSLS analysis yields F-probability as 0,000001, and this result shows that at α=0,01, simultaneously, environmental degradation, carrying capacity, the number of agricultural labour, farmland width, investment on agricultural industry, the number of population, credit allocated to agricultural sector, rural poverty rate, and dummy East Java Province Long Term Development Plan 2006-2025 are significant determinants of agricultural RGDP.

Based on the partial test (t-test), we know that investment in the agricultural industry, the number of population, and credit allocated to the agricultural sector are positively significant determinants of agricultural RGDP. It means that if the agricultural industry, the number of population, or credit allocated to the agricultural sector, *ceteris paribus*, agricultural RGDP will increase. Meanwhile, environmental degradation is a negatively significant determinant of agricultural RGDP.

Table 4. TSLS analysis result of agricultural RGDP

Variable	Coefficients	Probability	F-probability	Adjusted-R^2
C	$2{,}16.10^{13}$	0,3076	0,000001***	0,9553
DG	-0,116638	0,0572*		
CC	$6{,}5.10^{12}$	0,5835		
LAB	-1585568	0,1819		
LAND	-4551353	0,2192		
INV	0,036145	0,0349**		
POP	1409777	0,0213**		
CRD	1510366	0,0086***		
RPOV	$-2{,}11.10^{11}$	0,1026		
D1	$-1{,}24.10^{-14}$	0,3656		

= Significant at α=0,1; **= Significant at α=0,05; *= Significant at α=0,01*
Source: Data analysis, 2019.

3.3. Policy Simulation
We used *E-views 9* software to do a simulation with a simultaneous equation model, which is generated by TSLS analysis. Raising credit allocated to the agricultural sector is a policy alternative to decrease environmental degradation, increase environmental carrying capacity, and increase agricultural RGDP all at once. We tried to raise credit allocated to the agricultural sector for 15,1% (according to its average growth rate (BPS, 2015)).

Table 5. Simulation result of raising credit allocated to agricultural sector for 15,1% rate

Type of Value	Environmental Degradation Value (Rp. 000.000)	Environmental Carrying Capacity	Agricultural RGDP (Rp. 000.000)
Actual Average	23.520.596,60	1,0679	44.770.165,00
Simulated Average	22.961.472,00	1,0865	45.463.138,00
Gap (%)	-2,38%	1,72%	1,55%

Source: Data analysis, 2019.

Raising credit allocated to the agricultural sector as many as 15,1% is proven to decrease environmental degradation 2,38%, increase environmental carrying capacity 1,72% and increase agricultural RGDP 1,55%. Credit is one of the most critical resources to enhance farm management's performance. Accessing credit for agricultural activities increases farmers' ability to multiply their productivity by purchasing more input; thus, the increase of farmers' income. According to the EKC, an increase in income will lead farmers to assign environmental conservation cost for their farm management. This conservation will retain environmental capacity and decrease environmental degradation.

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Table 6. Simulation result of raising investment in agricultural, chemistry, and timber industry for 5% rate

Type of Value	Environmental Degradation Value (Rp. 000.000)	Environmental Carrying Capacity	Agricultural RGDP (Rp. 000.000)
Actual Average	23.520.596,60	1,0679	44.770.165,00
Simulated Average	23.486.430,00	1,0690	44.812.508,50
Gap (%)	-0,145%	0,103%	0,095%

Source: Data analysis, 2019.

Raising investment in agricultural, chemistry, and timber industry at 5% level is proven to decrease environmental degradation 0,145%, increase environmental carrying capacity 0,103%, and increase agricultural RGDP 0,095%. Investment in agricultural, chemistry, and timber industry represents many activities for manufacturing various harvest at down-stream of agribusiness. These activities can add more value to agricultural raw commodities and increase income indeed. Based on EKC, this condition could be a source of conserving capital.

4. Conclusion and Policy Implication

Economic development has a trade-off in the form of externalities that affect the environment, especially the agricultural sector. Growing population and food demand have to be emphasized as the challenges of providing sufficient food for the communities. High capital allocation for accessing external input not only can multiply food production but also can degrade the environment. This issue can be more difficult to answer by many developing countries because of their constraint on economic resources and high dependency on the agricultural sector (also environment certainly). This research tried to generate proper strategies to deal with environmental externalities yielded by the agricultural sector through macro-scope analysis. This research employed agricultural income as the principal value of production, while environmental capacity and environmental degradation as externalities. It revealed those three variables have a simultaneous correlation. Raising credit allocated to the agricultural sector and investment in agricultural, chemistry, and timber industry (agricultural manufacturing) is proven to decrease environmental degradation, increase environmental carrying capacity, and increase agricultural production all at once. This research encourages the government and other stakeholders to allocate more credit loan to the rural and agricultural area. The credit loan has to be invested in on-farm activities in order to gain higher productivity and to utilize the eco-friendly farming system. Furthermore, developing rural agroindustry has to be initiated and empowered to generate a better alternative for the rural/farm households in gaining more income. Gaining income from agroindustry could reduce their dependence on agricultural activities and even on exploiting environmental resources.

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