Comparison of Development Options in an Erosion-Prone Reservoir Area: A Case of Wonogiri, Central Java, Indonesia

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Wonogiri in Central Java, Indonesia, is an erosion-prone reservoir area. Though cultivation of mountainside slope is an important income source, it is the largest cause of rapid sedimentation in a downstream reservoir. In addition, it may not be a sustainable way of agriculture due to soil loss. For both sustainable regional economy and sustainable use of the reservoir, countermeasures for the upland crop field are being recommended. This research considered preferable development strategies, using estimated input-output data. Comparison of development scenarios implies that promotion of rice sector may be a preferable strategy.

Key words : input-output analysis, regional development strategy, sustainable development

1. Introduction

Wonogiri in Central Java, Indonesia, is a reservoir area, and supplies water to wide paddy fields along the Solo River. A multi-purpose dam for the reservoir was completed in 1981, and has been used for irrigation and flood control. However, more rapid sedimentation in the reservoir than expected before operation is recently observed, causing floods in rainy season and droughts in dry season [11].

The reason for the rapid sedimentation in the Wonogiri reservoir is considered to have two aspects, natural and social [5]. Natural aspect is that Wonogiri reservoir region is steep mountainous area with volcanic ash soil, which is vulnerable to erosion. Social aspect is increase in population and induced active economic activities including agriculture in steep mountainside.

With an aim to reducing sediment inflow into the reservoir down to the level of sustainable use of the reservoir, erosion prevention work for 34 thousand ha of total 67 thousand ha upland crop field in the catchment area is being recommended [4] because the area of 34 thousand ha is located in steep mountainside.

If the erosion prevention work is conducted, the work will also prevent, at least for several years, farming activities in the wide upland crop field as much as 34 thousand ha, which amounts to almost half of total upland crop field in the reservoir catchment area. In order to mitigate negative impacts of the prevention work on farmers and the economy of the region, it is preferable that alternative development strategies, which do not weigh on the environment and do enable sustainable development, are considered and applied.

This research estimated the magnitude of economic ripple effects of development options and considers preferable development strategies which can substitute and compensate for agricultural activity in steep mountainside. In order for various options to be analyzed, input-output analysis was applied, because the method can quantitatively compare alternative development scenarios. For conducting an input-output analysis, an input-output table was estimated for Wonogiri region.

According to our field survey in Wonogiri, there are some prospective sectors which may contribute to sustainable economic development. Based on the information, 3 alternative development scenarios were considered in this research. They are promotion scenarios of paddy rice production, poultry production, and tourism.

2. Methods and Data

1) Estimation of input-output data

Estimation was conducted through the following four processes. The first process was estimation of intermediate transactions among industries and value-added allocations. The second was estimation of final demand. The third was import and export transactions. The last was balancing of roughly estimated table for consistency.

Intermediate inputs and value-added allocations of agricultural sectors were estimated by supposing that input and value-added coefficients of Wonogiri are the same as that of Central Java. An input-output table for Central Java

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had been estimated by the provincial authority [8]. By multiplying productions in Central Java [7] with production quantity ratios of Wonogiri to Central Java, productions in Wonogiri were obtained. Production quantity ratios were obtained from respective statistics [7][10]. By multiplying productions in Wonogiri with input and value-added coefficients, intermediate inputs and value-added allocations were obtained.

Productions of manufactures and services in Wonogiri were obtained by dividing gross domestic products by sector [9] by value-added ratios from Central Java input-output table [8]. By multiplying the productions with input and value-added ratios, intermediate transactions and value-added allocations of manufactures and services were obtained.

Final demand is composed of private consumption, government consumption, and fixed capital formation. Private consumption was obtained by multiplying the consumption expenditure vector of a household income class in Central Java whose income is almost the same as the average household income of Wonogiri, with the number of households in Wonogiri. Expenditure vectors by income class were obtained from a national statistics [12]. Government consumption was abstracted from a regional official statistics [10].

In order to estimate fixed capital formation, estimation of private saving is necessary. Saving was obtained by supposing that the difference between estimated total value added and consumption expenditure in Wonogiri is saving. By multiplying the allocation vector of fixed capital formation calculated from the input-output table of Central Java with the sum of private saving and budget for public works [10], fixed capital formation was obtained.

Through the above processes, roughly estimated table was formed. The table includes some negative values. Therefore, RAS method cannot be used for balancing. Instead, Improved GRAS method [3] is applied for balancing. By balancing the table, a Wonogiri input-output table for 2008 with 80 industries was estimated.

2) Analysis of constraints on upland agriculture

According to an investigation of sedimentation problem in the Wonogiri reservoir [4], erosion prevention work such as terracing of slope for about half of entire the upland crop field in the catchment area is being recommended. If this work is adopted as a countermeasure for sustainable use of reservoir, agricultural activities in the target field may be subject to some restriction. As methods of estimation of economic impacts of supply constraints, Ghosh's forward linkage model [2] and the mixed input-output model [13] have been proposed. In this research, we employed Ghosh's forward linkage and general Leontief model [6] which expresses backward linkage because crop supply reduction due to land use restriction affects recipient industries of crops first through the forward linkage, and then lowered activities of recipient industries affect other industries through the backward linkage.

The decrease in production due to land use restriction is obtained by the following equation based on the Ghosh model:

$$\Delta X_f^T = \Delta V (I - B)^{-1} \tag{1}$$

where ΔX_f^T is the row vector of production decrease induced by forward linkage, ΔV is the row vector of reduction of economic activities measured by value added, I is the identity matrix, and B is the output coefficient matrix.

The decrease in production due to decrease in intermediate demand is calculated by the following equation:

$$\Delta X_b = \left\{I - \left(I - \widetilde{M}\right)A\right\}^{-1} \Delta X_f \tag{2}$$

where ΔX_b is the column vector of production decrease induced by backward linkage, $\widetilde{M}$ is the diagonal matrix of import coefficients, A is the input coefficient matrix, and ΔX_f is the column vector as the transpose of ΔX_f^T.

Total decrease in production induced by both linkages is the sum of each decrease as follows:

$$\Delta X_d = \Delta X_b + \Delta X_f \tag{3}$$

where ΔX_d is the total decrease.

3) Analysis of ripple effects of development options

Ripple effects of development options are estimated based on Leontief model [6]. However, by the basic assumption of this research, a production constraint is imposed on upland crop sector. Following an assumption of previous study [1] that excess demand for a constrained product is met by import, a ripple effect of a development option is described by the following equation:

$$\Delta X = L \cdot \Delta F - L \cdot \widetilde{D}\left[L(F + \Delta F) - \overline{X}\,\right]_+ \tag{4}$$

where ΔX is the column vector of production change as a result of a ripple effect, L is the Leontief inverse matrix, ΔF is the column vector of final demand change determined by a development option, $\widetilde{D}$ is the diagonal matrix of inverse numbers of on-diagonal elements of L, F is the column vector of initial final demand from reference data, $\bar{X}$ is the column vector of production constraints, and $[\cdot]_+$ is the column vector consisting of non-negative elements of vector $[\cdot]$, which denotes excess demand over production constraints, $\bar{X}$. The first term of right hand side of equation (4) means additional production induced by final demand change. The second term means decrease in induced demand caused by the replacement of domestic production for excess demand over constraints with import products.

The Leontief inverse matrix, L, in equation (4) is derived from the following equation.

$$L = \left\{I - \left(I - \widetilde{M}\right)A\right\}^{-1} \tag{5}$$

Change in final demand, ΔF, is derived from the following equation:

$$\Delta F = \Delta E + \left(I - \widetilde{M}\right)\Delta C \tag{6}$$

where ΔE is the change in export and ΔC is the change in consumption.

3. Results and Discussion

1) Characteristics of Wonogiri economy

Based on the estimated input-output table of Wonogiri, we examine the characteristics of Wonogiri economy. Though the estimated input-output table has 80 industrial sectors, an aggregated table with 30 sectors is used here to express distinctive characteristics of Wonogiri economy.

Figure 1 shows share of gross domestic product (GDP) by industrial sector. Upland crops has the largest share (32%) followed by retail and wholesale trade (13%), transportation (9%), government and security (9%), and rice (7%). Rice sector comprises paddy rice and upland rice. According to our field survey, upland rice is cultivated not in steep mountainside but in dry upper delta. The total share of agricultural sectors amounts to 51% of the GDP. This result implies that agriculture is a central economic activity which produce large portion of economic value in Wonogiri. Above all, upland crops has the prominently largest share of 32%. Therefore, this activity is the most important one in terms of local economic value. However, it is said that cultivation of slope land for upland crops is the largest source of mountainside erosion and reservoir sedimentation [4]. These facts make us understand that good balance between economic development in Wonogiri and sustainable use of Wonogiri reservoir is an unavoidable challenge.

Figure 2 shows a skyline chart of Wonogiri economy derived from the estimated input-output table. According to this chart, sector of upland crops has the largest shares both in production (horizontal axis) and self-sufficiency (vertical axis). On the other hand, self-sufficiency rates of food processing, other manufactures, utilities, and construction are remarkably low. These facts imply that Wonogiri economy earns fund for buying manufactured goods by selling upland crops.

2) Impact of land use constraint on the economy

Upland crop field in steep mountainside is the main source of sediment into the downstream reservoir. Therefore, we estimated a negative ripple effect of land use constraint on upland crop field, namely, a reduction of 34 thousand ha

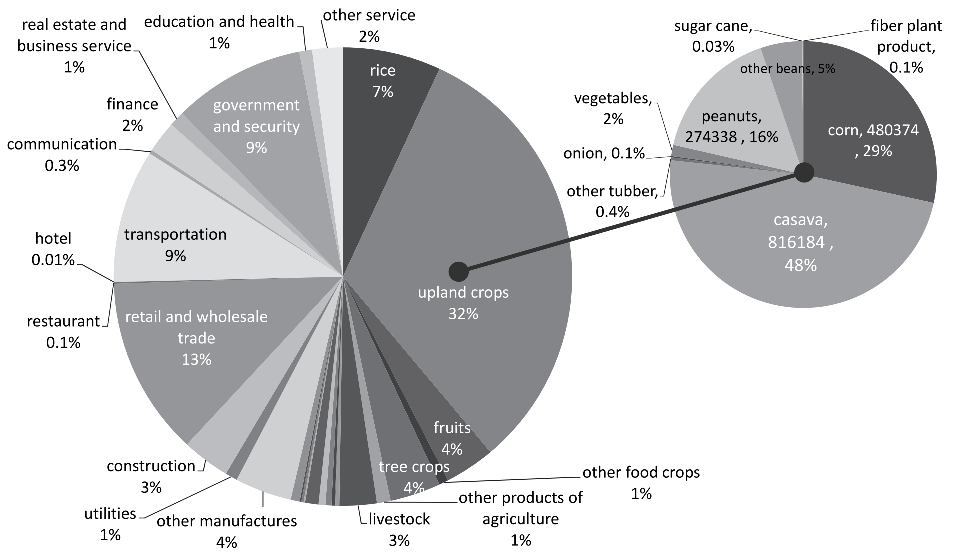

Figure 1. GDP share by industrial sector based on the estimated input-output table of Wonogiri for 2008

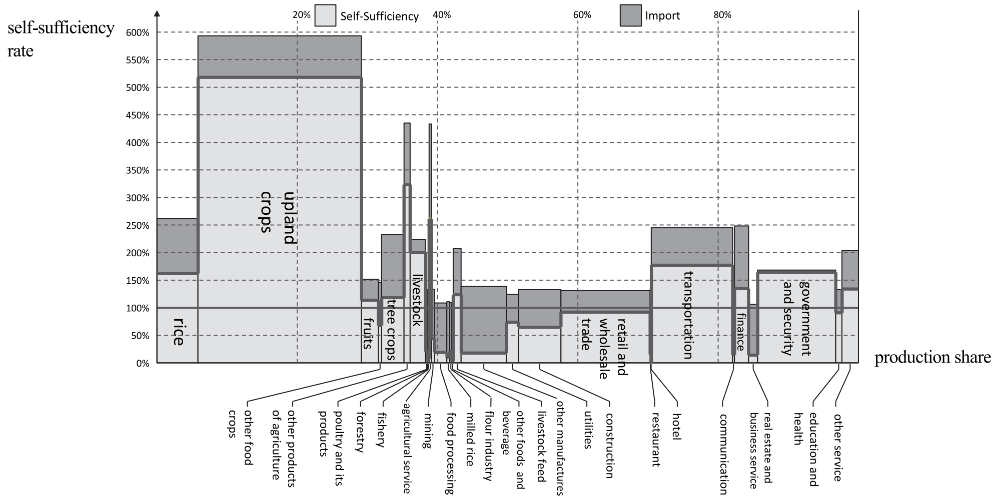

Figure 2. Skyline chart of Wonogiri based on the results of input-output analysis

in steep mountainside. Table 1 shows GDP decrease by sector. Assumed constraint is that farmers cannot cultivate 34 thousand ha of upland crop field in Wonogiri. “Forward” is estimated by equation (1), “backward” is by equation (2), and “total” is by equation (3). According to the result, total decrease in GDP amounts to 932 billion Rp., which is 17.6% of actual regional GDP in 2008. Of all sectors, upland crops (sector 2) has the largest decrease of 873 billion Rp., which explains 94% of total decrease. Within upland crops, considerable portion of decrease is due to forward linkage effect (820 billon Rp., 94%). These results mean that due to land use constraint on upland crops, people in the economy will lose nearly 20% of economic value. Considerable part of the economic loss can be explained by production reduction of upland crops itself. This is consistent with the fact that large portion of products of the sector is for export as shown in Figure 2. This result also implies simplicity of input-output structure in the region.

3) Ripple effects of development options

As discussed above, land use constraint on 34 thousand ha for upland crops would reduce 17.6% of GDP in Wonogiri. We are interested in whether prospective development scenarios can compensate for the loss or not. In order to investigate feasibility of development scenarios, we explore necessary increase in final demand and corresponding necessary production for the recovery of GDP, using equation (4).

Table 2 shows prospective development scenarios based on our field survey and results of exploration. Development scenarios to be investigated are “Rice value improvement”, “Poultry production promotion”, “Domestic tourism promotion”, and “International tourism promotion”.

Comparison of necessary increase in production among the four scenarios implies efficiency of Rice scenario. In Rice scenario, production value of rice needs to grow 3.29 times as much as the present value by additionally supplying 966 billion Rp. of rice for the final demand. In

Table 1. Decrease in GDP due to land use constraint on upland crops (million Rp.)

sector	forward	backward	total
1 rice	441	484	924
2 upland crops	820,054	53,385	873,440
3 fruits	128	398	526
4 other food crops	17	763	780
5 tree crops	287	243	530
6 other products of agriculture	1,065	76	1,141
7 livestock and its products	3,924	5,563	9,487
8 poultry and its products	750	71	821
9 forestry	3	27	30
10 fishery	220	65	285
11 agricultural service	238	2,951	3,189
12 mining	43	637	680
13 food processing	1,525	119	1,644
14 milled rice	6	8	14
15 flour industry	801	120	921
16 other food and beverage industry	668	11	679
17 livestock feed industry	5,487	884	6,372
18 other manufactures	1,988	950	2,939
19 utilities	216	315	531
20 construction	782	3,958	4,740
21 retail and wholesale trade	1,507	9,541	11,048
22 restaurant service	146	61	207
23 hotel	13	2	15
24 transportation	1,760	3,205	4,965
25 communication	20	93	113
26 finance	164	324	488
27 real estate and business service	166	125	290
28 government and security	3,839	66	3,906
29 education and health	155	108	263
30 other service	485	759	1,244
total	846,899	85,312	932,211

Table 2. Development scenario and result of exploration

Development scenario			Result of exploration by equation (4)	
	Name	Contents	Necessary growth level	Necessary increase in final demand
a)	Rice value improvement	Instead of upland farming, quality and quantity of rice are increased.	Value of rice production needs to grow 3.29 times as much as the present value.	966 billion Rp.
b)	Poultry production promotion	Instead of upland farming, local variety chicken is raised.	Value of chicken and egg needs to grow 47.6 times as much as the present value.	1,113 billion Rp.
c)	Domestic tourism promotion	Instead of upland farming, tourism to attract people from outside is promoted.	The number of domestic tourists needs to reach 1,380,000.	1,298 billion Rp.
d)	International tourism promotion		The number of international tourists needs to reach 415,000.	1,301 billion Rp.

Wonogiri, some farmers have already achieved high yield of rice production. While the average paddy rice yield in Wonogiri is 5.6 ton/ha [10], some farmers who introduced system of rice intensification (SRI) have achieved more yield than 10 ton/ha [14]. Therefore, the estimated necessary growth level of Rice scenario seems relatively realistic and feasible. In Poultry scenario, the sector of poultry and its products needs to grow 47.6 times as much as the present value, realizing additional 1,113 billion Rp. supply to final demand. In order to achieve this growth in the sector, large amount of investment in poultry and its products is required. Domestic tourism scenario needs 1,380 thousand visitors per year. International tourism scenario needs 415 thousand visitors from foreign countries. In order to attract such a large number of visitors, huge amount of investment is required.

Figure 3 explains the difference of efficiency among the development scenarios. The horizontal axis shows upland crop inducement coefficient to measure the power to induce upland crop production. The vertical axis shows value-added multiplier to measure the power to induce income. Both the indices are derived from Leontief invers matrix in equation (5). As for Wonogiri, low value in upland crop inducement coefficient and high value in value-added multiplier are preferable because economic development without depending on upland crops would be sustainable. Rice sector is located in the most preferable area. Poultry and its products, which is the target sector of Poultry scenario, has relatively high value in value-added multiplier. However, upland crop inducement coefficient is also high. Therefore, promotion of this sector will induce upland crop production, resulting in the increase in substitutive imports. Sectors related to tourism are education and health services, hotel, restaurant, and transportation. Their power to induce regional value added is medium. Therefore, more production, so many visitors, and much amount of investment fund are necessary for GDP recovery.

4. Conclusion

This research has clarified characteristics of Wonogiri

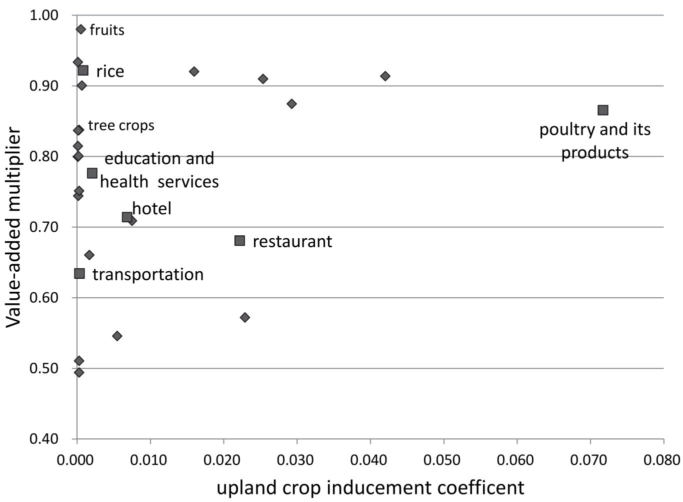

Figure 3. Key sector diagram of Wonogiri economy

economy, based on the estimated input-output table. In addition, this research has compared development scenarios under the assumption of land use constraint on upland crop agriculture, in order to search for appropriate alternative development strategies.

Estimated input-output data imply that Wonogiri region is strongly dependent on agricultural sectors for earning income to obtain manufactured goods supplied by other regions. In particular, upland crops, which are grown in erosion-prone slope land, have the largest contribution to GDP of the region. Therefore, achieving good balance between sustainable land use and short term economic efficiency is an important and unavoidable challenge.

Results of comparison of development scenarios imply that promotion of sectors with high efficiency for earning regional value added is preferable. However, promotion of sectors which have strong power to induce the production of upland crops is not efficient because they will increase imports of upland crops as substitution for regional production. In addition, in order to compensate for large income loss due to the constraint on upland crops, a certain degree of potential for additional production is necessary because small scale sectors need much amount of investment fund for growth. Production of high quality and high yield rice in Wonogiri seems to meet these preferable conditions, and it is one of promising strategies.

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