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SUSTAINABLE IRRIGATED FARMING SYSTEM (SIFS) MODELING AT THE HOUSEHOLD LEVEL IN THE NORTH COASTAL PLAIN OF BALI

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ABSTRACT

Intensive farming of low fertility soil with limited water source can lead to trade-off between economic benefits in the short run, and environmental problems in the long run. Environmental degradation and inefficient resources allocation will affect unsustainable farming systems. This study aims to develop Sustainable Irrigated Farming System (SIFS) Model at the household level in the north coastal plain, Bali. Primary data from 42 farmers by using survey method in representative scheme and secondary data from various sources were used to specify parameters of the model. Linear programming analysis was used to solve the constrained optimization problem. A small farmer with 0.556 ha land holding was efficient in resources allocation as indicated by optimal solution of Conventional Irrigated Farming System (CIFS) Model which conforms to observed behavior. By several adjustments, the CIFS Model can be extended to the SIFS Model. To achieve the SIFS condition, the farmers should be able to apply: the groundwater at less than or equal to 8.547 L s^{-1}, organic fertilizer from manure at more than or equal to 5 $t{\bullet}ha^{-1}{\bullet}yr^{-1}$, mixed-farming system and crops rotation, minimum household expenditure, and water price by Rp1,218.29 m^{-3} into the model.

Key words: farm modeling, sustainable agriculture, household level

INTRODUCTION

To form a sustainable industrial agriculture system with high competitiveness and to warrant food security and farmer's welfare was the vision of Indonesian's agricultural development in 2025 (Ibrahim, 2008). One of its characteristics is optimal and sustainable use of resources such as land, water, germ plasma, labor, capital, and technology (Kasryno et al., 1997). Fagi (2003 *in* Sugino, 2003) introduced two key issues for agricultural development: sustainability and diversity. In 1990s, sustainability has become a significant issue internationally related to the concern about conservation and environment, as well as a critical remark to the "Green Revolution" that only focus on how to produce large quantities of food for the current year (Brady, 1990).

SEARCA (1995) defined sustainable agriculture as a holistic farming system that are economically viable, ecologically sound, socially just, and culturally and technically appropriate. Basic principles of sustainable agriculture are (1) eliminating industrial production method and finding the effective, productive and inexpensive of external input system; (2) including more farmers, recognizing and understanding to indigenous knowledge for agricultural and natural resources management; and (3) conserving the active resources that integrated into production framework (Shepherd 1998). Virmani and Eswaran (1990 *in* Maji, 1991) suggest that the criteria for evaluating the sustainability of the agricultural system included assessment of risks, assessment of production technology performance, stability of the system, impact of the farming system on the degradation of natural resources, particularly soil and water and the profitability of the system.

Dixon and de Los Reyes (1990 *in* Widodo, 1993) asserted the sustainability as constrained optimization to maximize benefit subject to natural resource base maintenance. Farming system research (FSR) is very helpful and very useful in achieving the goals of sustainable agriculture (Widodo, 1993). FSR can use the optimization of mixed farming system model by using linear programming (LP) analysis. The LP model is based on input-output relationship for each crop and livestock subject to the availability and maintenance of natural resources. LP model can be used to test the on-farm efficiency of resource use (Standen, 1972). However, the success of sustainable development of agriculture strongly depends on two important factors, i.e. best management practices in farming system development (FSD) and government intervention (Sugino, 2003).

Intensive FSD on low fertility soil with limited water source under the Sustainable Development of Irrigated Agriculture in Buleleng and Karangasem (SDIABKA) Project (2003-2006) can lead to trade-off between economic benefits in the short run and environmental damages in the long run. Only 3.6 MCM (12 %) of groundwater flowing might be remained and recommended (PMU, 1995) to support mixed-farming system development (M-FSD) in the project area, annually. Depletion of the groundwater resource can due to high abstraction (ADB, 1998). As environmental degradation increases and inefficient in resources allocation will eventually affect to unsustainable agriculture (Sugino and Hutagaol, 2004). Thus, good agricultural practices must be considered. Moreover, to realize the SIFS, economic as well as environmental costs must be taken into account (Berbel and Gomez-Limon, 1999; Small, 2003).

The project has been jointly financed by the European Commission and the Government of Indonesia. The cost is €6,625,000, contributed by EC €6,125,000 and GOI €500,000 only (PMU, 2003). Thirty nine schemes of irrigation system under the project are to support M-FSD. But, the M-FSD was conventionally operated. Water pricing as an indicator just based on operation and maintenance (OM) costs and yet to reflect the full cost or sustainable value in the use of water. Rogers et al. (1998) defined the full cost of water as sum of OM costs, capital charges, opportunity cost, and economic and environmental externalities. In addition, irrigation was fully subsidized by the project.

This study aimed to develop the SIFS Model at household level in north coastal plain, Bali. The specific objective was to analyze the optimization of groundwater irrigation-based farming system at household level by using linear programming (LP) analysis and to assess its sustainability.

METHODOLOGY

As a representative scheme, TMB-59 was purposively chosen from 39 schemes under the project. Primary and secondary data based on sustainable agriculture indicators were used to specify parameters of the model. The primary data were collected from 42 farmers, chosen by census procedure while secondary data were gathered from appropriate sources. The arithmetic mean of the observed parameters can be used in LP analysis (Timmer, 1971 *in* Soekartawi, 1996).

$BLPX_{88}$ (Eastern Software Product, Inc., 1984) was used to solve the constrained optimization problem for irrigated farming system at household level. Essentially, LP is a formal mathematical technique which selects the combination and the levels of activities, from the set of all feasible activities, and a specified objective function is reached without violating the resource and any other specified constraints (Barlow et al., 1977). The objective function in this study is to maximize net cash flow plus liquidity value of reserve cash and credit for irrigated farming system at household level subject to constraints imposed by his farm land, labor supply, groundwater abstraction, organic and/or inorganic fertilizers and pesticides inventory, perennial crops inventory, annual and seasonal crops seed inventory, livestock and feed inventory, household consumption plus unexpected expenses, and so forth.

Specifically, constrained optimization problem for the irrigated farming system at the household level can be illustrated as follows:

Maximize: $z = c_1 x_1 + \ldots + c_j x_j + \ldots + c_n x_n + c_l x_l$

subject to:

$$a_{i1} x_1 + \ldots + a_{ij} x_j + \ldots + a_{in} x_n \leq b_i$$

$$a_{ca1} x_1 + \ldots + a_{caj} x_j + \ldots + a_{can} x_n + a_{cal} x_l = cash$$

$$a_{cr1} x_1 + \ldots + a_{crj} x_j + \ldots + a_{crn} x_n + a_{crl} x_l \leq credit$$

$$a_{e1} x_1 + \ldots + a_{ej} x_j + \ldots + a_{en} x_{nl} \geq household \;\; expenditure$$

$$a_{l1} x_1 + \ldots + a_{lj} x_j + \ldots + a_{\ln} x_n + a_{ll} x_l \geq liquidity$$

where z is the objective function; x_j*'s* are the activity alternatives; b_i*'s* are the constraints; a_{ij} is an addition to (< 0) or substraction from (> 0) b_i by a unit of x_j; c_j is an addition to (> 0) or subtraction from (< 0) z by a unit of x_j; a_{ca} /a_{cr} is the level at which cash/credit decreases (> 0) or increases (< 0) by choices in production, consumption, marketing and finance including reservation of cash/credit; a_{lj} is the addition to (< 0) or satisfaction of (> 0) liquidity by a unit of x_j; a_{ll} is the rate at which reservation cash and credit satisfy the requirements; c_l is value associated with forms and levels of reservation, x_l; a_{ej} is the addition to (< 0) or satisfaction of (> 0) household expenditure by a unit of household consumption plus unexpected household expenses activity.

RESULTS AND DISCUSSION

The Study Area and Socioeconomic Characteristics of Farmers

Coastal plain like in the project area is generally a region with poor soil, high water losses through percolation, high evapotranspiration and run-off, and groundwater as being primary water source. The project area which is approximately 5,300 ha with 30 km long and varies in width between 1 and 3 km, involves 12 villages in Buleleng and Karangasem Regencies. The interface depth at one km from the sea is over 100 m for all of the project area and at 100 m from the sea is between 35 m and 50 m below sea level. The project is also supported by 13,500 ha of catchment area (PMU, 1995).

About 2,015 farmers were covered in the project to include those who organized 39 water user associations (WUA) for 39 schemes of groundwater irrigation system, were introduced by the project with profitable mixed-farming practices and procedures for FSD on approximately 703 ha effective area (PMU, 2003).

One of the schemes with well code of TMB-59, located in Tembok Village, Tejakula District, Buleleng Regency, was chosen as a study area since farm modeling with a linear programming analysis has never been done by an independent party. A good performance of irrigated M-FSD at household level in TMB-59 also became an important reason. Three seasons, i.e. dry season 1 (DS1) from April to July, dry season 2 (DS2) from August to November, and rainy season (RS) from December to March were considered to be a complete period for covering the mixed-farming activities, annually, due to the average number of rainfall from April to November was less than 100 mm monthly, while from December to March, the number was greater than 100 mm.

The pump debit of the well in supporting the M-FSD has 14.4 L s^{-1} (PMU, 2005). It has actually operated 12 hours per day for 240 days in DS1 and DS2 and one hour per day for 120 days in RS. Thus, the average permissible pump debit based on 12 % discharge of annual flowing in the project area should be 8.547 L s^{-1}. The WUA of TMB-59 has 42 members; therefore, the groundwater limit for each member is about 1,054.9 m^3, 1,054.9 m^3, and 87.9 m^3 for DS1, DS2, and RS, respectively. Then, based on the laboratory analysis, the groundwater is of good quality for competitive use between domestic water supply and agricultural water requirement.

The average farm size operated by farmers in the study area is 0.556 ha. The land was consists of perennial crop area (0.446 ha), annual crop area (0.0995 ha), and seasonal crop area (0.124 ha), as well as remained area for livestock farming. The soil characteristic is mostly inceptisol order with soil depth more than 50 cm, sandy loam, and rather hard texture class, C-organic less than 2 %, pH more than 0.5, and saturation base more than 50 %, low level of cation exchangeable capacity (5 < CEC < 16 me/100gr) and organic matter content. Therefore, it is potentially categorized as marginal suitable (S3) for maize, cassava, groundnuts, sweet potato, melon, chili, banana, cashew, coconut, and palmyra palm, and suitable enough (S2) for mango, papaya and fodder grasses (Budiasa and Mega, 2007).

Membership in the WUA was required by the project in order to manage groundwater irrigation system, develop mixed-farming activities, as well as conduct farmer meeting, extension, and training. The average of member age and formal education in this case were 49.6 years old and 3.8 years, respectively. Then, the average of household size was 4.8 members including the respondent, grandparents, grandchild, etc. One of the household members was enrolled in school. The oldest children and adults were primarily source for non-farm labor and remaining source for farm labor and/or fisherman.

Before the project development, from 1970 to 1980, local farmers were prosperous because of their success in citrus farming. But, in 1980s it was not still economically viable due to the viruses attack. Then, local farmer replaced citrus with other perennial crops such as mango, coconut, cashew, palmyra palm, etc. Several crops such as maize, groundnuts, and cassava were only seasonally grown under coconut trees in rainy season. Farm income from the latter crops has less than the income from citrus farming. Other farmers usually raise cattle in the rainy season and sell these in the dry season.

The project has likely been successful in changing the farmers' behavior in resources allocation. A number of perennial crops such as mango and palmyra palm were replaced by annual crops and seasonal crops. New seasonal crops which offer good returns are chili, melon, and sweet potato. New annual crops are banana, fodder grasses, and papaya as wells as livestock enterprises such as cattle, pig, chicken, and goat also offer good income for local farmer.

The Mixed-Farming System and Cropping Pattern

Attempting to offset production risk and to realize sustainable use of available resource, the farmer in TMB-59 operates mixed-farming system (Fig. 1). Crops in the study area were typically divided into three class i.e. perennial crops, annual crops, and seasonal crops. Perennial crops such as mango, coconut, cashew, and palmyra palm had been existed before while annual crops such as banana, papaya and fodder grasses were introduced by the project. Seasonal crops which offer good returns such as chili, melon, sweet potato were also introduced by the project while maize, groundnut, and cassava were traditionally planted by farmer.

Banana, papaya, fodder-grasses, and chili were developed in the beginning of DS1 while melon was planted in May. Sweet potato, intercropped maize-groundnut, intercropped maize-cassava, and cassava were planted in DS2 while maize by monoculture system was planted in RS. Most crops such as banana, papaya, fodder-grasses, chili, melon, and sweet potato were also grown in the dry season since crop water requirement can be met by the groundwater irrigation system. In addition, livestock such as cattle, pig, chicken, and goat were produced annually.

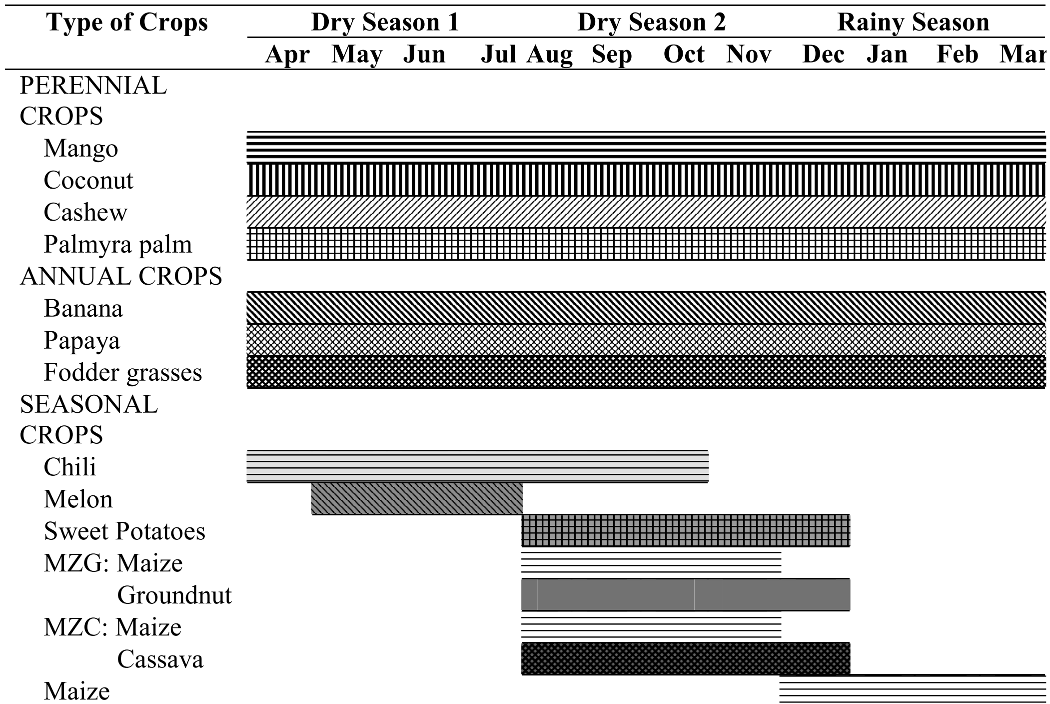

Fig. 1. Cropping pattern under the sustainable farming system

The Conventional Irrigated Farming System Model

The CIFS model was specified as representative of existing conditions under observation. This farm unit is identified in terms of crops and livestock production, household consumption and unexpected expenses, marketing, fishing, financing including liquidity reservation, off-farm and non-farm activities. The optimization results that were assessed in terms of conformity of results with observations are provided in Table 1**.** The confidence interval was utilized to test null hypothesis that optimal values of the model do not differ significantly from the survey mean. The zcceptance of such null hypothesis means that the model conforms to the observations.

Table 2 provides the valuation results by using sustainability criteria to the validated model. Based on the table, the CIFS Model which expressed existing condition can be categorized as a conventional farming system since its optimal levels failed to fulfill the criteria of sustainability. In this case, groundwater abstraction in DS1 is actually greater than the permissible groundwater abstraction by equal or less than 1,054.9 m^3 in DS2. This condition will lead to groundwater source depletion. In addition, groundwater pricing was still very simple and only based on the operation and maintenance component costs. Whereas, the simple cost of water was fully subsidized by the project. The subsidy and simple water cost was economically inefficient for water allocation. Also, the model which ignored inflation effect and liquidity reserve of cash and credit did not respond to financial risk. Accordingly, environmental, economical and risk assessment criteria were not fully considered in the CIFS Model.

Table 1. The optimal levels from the CIFS Model and observed mean from a survey.

Activities	CIFS Model	Survey Mean	Standard Deviation	Confidence Interval
1. Objective function (000Rp)	3,606.85	n.a.	n.a.	n.a.
2. Farm-land use (ha)	.556	.556	.342	.415 - .697
3. On-farm production:				
PERENNIAL CROP (ha)	.4395	.446	.361	.298 - .595
- Mango (tree)	25.00	25.76	20.43	17.33 - 34.19
- Coconut (tree)	17.6	17.6	23.29	7.98 - 27.20
- Cashew (tree)	8	8	10.78	3.55 - 12.45
- Palmyra palm for sap (tree)	1.9	1.9	3.27	.89 - .2.91
- Palmyra palm for fruit (tree)	3.1	3.1	4.17	2.02 - 4.59
Annual crop (ha)	.0809	.0995	.0702	.0701 - .1284
Seasonal crop (ha)	.0988	.124	.1239	.0732 - .1754
Cattle 3 (100 kg)	6.26	6.62	4.91	4.07 - 9.77
4. Organic fertilizer (t yr^{-1})	2.995	2.89	1.89	2.11 - 3.67
5. Buy inorganic input:				
- Urea (kg) DS1	29.22	37.40	25.81	26.25 - 48.05
Urea (kg) DS2	84.26	144.22	90.32	107.36 - 181.88
Urea (kg) RS	32.83	32.66	29.46	20.51 - 44.82
- SP36 (kg) DS1	13.93	16.95	18.05	9.50 - 24.39
SP36 (kg) DS2	18.42	25.3	14.79	19.19 - 31.40
- KCl (kg) DS1	17.69	23.00	20.55	14.53 - 31.48
KCl (kg) DS2	27.63	37.95	22.19	28.79 - 47.11
- NPK (kg) DS1	21.08	27.97	20.67	19.44 - 36.49
NPK (kg) DS2	8.32	8.296	21.54	-.59 -17.18
NPK (kg) RS	3.89	3.095	11.31	-1.57 - 7.76
- ZA (kg) DS1	3.08	3.12	8.97	-.58 - 6.82
- $KN0_3$ (kg) DS	.88	1.00	2.93	-.65 - 2.65
- Dolomite (kg) DS1	344.71	430.15	313.19	300.95 - 559.35
- Power growth stimulator (L) DS1	.74	.86	3.54	-.60 - 2.32
- Furadan (kg) DS1	.044	.044	.095	.005 - .084
- Diazinon (L) RS	.345	.35	.55	.114 - .568
6. Household expenditure				
- DS1 (000Rp)	3,401.93	3,401.93	1,280.76	2,873.5 – 3,930.3
- DS2 (000Rp)	3,401.93	3,401.93	1,280.76	2,873.5 – 3,930.3
- RS (000Rp)	3,401.93	3,401.93	1,280.76	2,873.5 – 3,930.3
7. Buy groundwater				
- DS1 (m^3)	676.10	786.68	548.11	560.56 - 1012.8
- DS2 (m^3)	1,099.74	1,167.94	724.03	869.26 - 1466.6

Activities	CIFS Model	Survey Mean	Standard Deviation	Confidence Interval
- RS (m^3)	79.61	210.96	138.4	153.84 - 268.04
8. Borrow from informal credit				
- DS1 (000Rp)	315.12	315.12	1,272.79	-130.4 - 760.7
- DS2 (000Rp)	103.93	103.93	565.69	-94.1 - 301.9
- RS (000Rp)	159.76	159.76	141.42	110.2 - 209.3
9. Fishing				
- DS1 (trip)	2.57	2.57	4.98	1.03 - 4.11
- DS2 (trip)	2.57	2.57	4.98	1.03 - 4.11
10. FMET				
- DS1 (time)	10.42	10.42	4.09	8.74 - 12.12
- DS2 (time)	6.33	6.33	2.08	5.47 - 7.19
- RS (time)	8.14	8.14	2.67	7.04 - 9.25

Note: n.a.= not available

Table 2. Valuation results to the CIFS (validated) model

Management practices	Sustainability indicators	Sustainability requirement	Analysis results	Achievement of sustainability criteria
Irrigation management	Groundwater quality	Non saline	Good quality	Safety for domestic and agriculture uses
	Groundwater extraction	≤ 1,054.9 m^3 $DS1^{-1}$	676.1 m^3 $DS1^{-1}$	Ecologically sound
		≤ 1,054.9 m^3 $DS2^{-1}$	1,099.74 m^3 $DS2^{-1}$	**Environmentally degrading**
		≤ 87.91 m^3 RS^{-1}	76.61 m^3 RS^{-1}	Ecologically sound
	Pump debit	< 25 L s^{-1} [a)]	14.4 L s^{-1}	Technically appropriate
	Irrigation subsidy	No subsidy	Rp997.46 yr^{-1}	**Economically inefficient**
	Groundwater pricing	Rp1,218.29 m^{-3} [b)]	Rp300 m-^{3}	**Economically inefficient**
Land (soil nutrient) management	Soil fertility	Fertile soil	Sandy loam texture, CEC 5-16 me/100g, C-org < 2%	Non fertile soil
	Soil erosion	<14.4 t•ha^{-1}•yr^{-1} [c)]	2.036 t•ha^{-1}•yr^{-1}	Very light
	Organic fertilizer use	> 5 t•ha^{-1}•yr^{-1} [d)]	5.386 t•ha^{-1}•yr^{-1}	Environmentally non-degrading
	Land suitability	CEC >16 me $100g^{-1}$	CEC 5-16 me $100g^{-1}$	S2 & S3 [e)]
Mixed-farming	Cropping pattern	Multiple cropping and choose profitable crops	Conducted	Technically appropriate and economically

Management practices	Sustainability indicators	Sustainability requirement	Analysis results	Achievement of sustainability criteria
system				profitable
	Cattle	> 386.1 kg yr^{-1}	838 kg yr^{-1}	Related to organic fertilizer requirement
	Fishing	5.14 trip yr^{-1}	5.14 trip yr^{-1}	
Integrated pest management	Cropping pattern	Crop rotation	Conducted	Environmentally sound
Risk management	Household expenditure requirement	≥Rp11,736,660 yr^{-1}	Rp10,205,790 yr^{-1}	Risk-averse farmer
	Inflation level 1997 to 2006	15 %	Ignored	**Involves financial risk**
	Liquidity reserve requirement	≥ Rp3,357,270 yr^{-1}	Ignored	**Involves financial risk**
Human and social capital management	Family labor distribution	≤ 46.39 man- days mt^{-1}	32.39 – 48.64 man- days mt^{-1}	Socially acceptable
	Membership in organization	WUA member	Active member in WUA of *Sarining Pertiwi*	
	FMET	24.89 man days yr^{-1}	24.89 man days yr^{-1}	
Goal	Objective function	Maximize net cash flow without liquidity reserve of cash and credit	Rp3,606,850 yr^{-1}	Economically viable **but involves financial risk**

Notes:
DS1 = dry season 1; DS2 = dry season 2; RS = rainy season; FMET = farmer meeting, extension, and training (participatory in irrigated farming system development; [a)] Arif and Pusposutardjo 1994; [b)] Budiasa 2008; [c)] Greenland and Lal (1975 *in* Nuarsa 1991); [d)] Based on the research finding by Sukartaatmadja *et al.* 2003; [e)] S2: suitable enough for mango, papaya and fodder grasses and S3: marginal suitable for maize, cassava, groundnuts, sweet potatoes, melon, chili, banana, coconut, cashew, and palmyra palm (Budiasa and Mega 2007)

Transformation from the CIFS Model to the SIFS Model

Some adjustments aimed to reform the CIFS Model were introduced to transform it to the SIFS Model, i.e.: (1) replacing actual groundwater abstraction by the permissible usage; (2) adjusting simple water pricing with full cost of water; (3) eliminating the irrigation subsidy from the beginning cash supply; (4) considering inflation effect and cash and credit reservation as an attempt to respond to risks; (5) considering minimum use of organic fertilizer; (6) keeping mixed-farming and crops rotation as an IPM strategy; (7) replacing existing labor usage with potential labor supply; and (8) improving farm technologies. Table 3 provides the changes of optimal levels generated from the SIFS model due to simultaneous adjustments to the CIFS model. The former was seemingly more ecologically sound than the later, indicated by the optimal levels of organic fertilizer usage in amount of 8.471 t ha^{-1} yr^{-1} (>5 t•ha^{-1}•yr^{-1}). The number which is important to prevent soil erosion in the study area, increased from 2.036 t•ha^{-1}•yr^{-1} (Budiasa and Mega, 2007). This result has a good relation with erosion level by 2.04 t•ha^{-1}•yr^{-1} from experimental results with mean gradient slope of nine percent and cow manure dosage by 5 t•ha^{-1}•yr^{-1} (Sukartaatmadja et al, 2003). The groundwater and inorganic fertilizers usages are lower than the actual values. The preference of inorganic fertilizer application, less than the actual level, indicated that the model allows the low external input for sustainable agriculture (LEISA).

Table 3. The change in optimal level results due to transformation from the CIFS Model to the SIFS Model

Sustainability Criteria by SEARCA (1995)	Survey Mean (Actual level)	Farming System Models CIFS	SIFS
ECONOMICALLY VIABLE, EFFICIENT, AUTONOMOUS:			
a. The value of objective function (Rp000 yr^{-1})	-	3,606.85	9,372.44
b. Irrigation subsidy (Rp000 yr^{-1})	997.46	997.46	0.00
c. Groundwater price (Rp000 m^{-3})	300.00	300.00	1,218.29
d. Inflation by 15 %	Ignored	Ignored	Included
ENVIRONMENTALLY SOUND:			
a. Groundwater limit (m^3 yr^{-1})	2,165.58	1,855.44	1,853.89
b. Composition of organic fertilizer (OF) in t•ha^{-1}•yr^{-1} and inorganic fertilizer (IOF) usage in kgs•ha^{-1}•yr^{-1} related to soil nutrient management.	OF: 5.190 > 5 IOF: 1,422.58	OF: 5.386 > 5 IOF: 1,088.92	OF: 8.471 > 5 IOF: 1,297.46
c. Integrated pest management	Crop rotation	Crop rotation	Crop rotation
SOCIALLY ACCEPTABLE	FMET, institutionalized in WUA	FMET, institutionalized in WUA	FMET, institutionalized in WUA
TECHNICALLY AND CULTURALLY APPROPRIATE	Irrigation technology (14.4 L s^{-1} < 25 L s^{-1}) without farm technology improvement	Irrigation technology (14.4L s^{-1}<25L s^{-1}) without farm technology improvement	Irrigation technology (8.547 L s^{-1} <25 L s^{-1}) with farm technology improvement
RISK MANAGEMENT:			
a. Diversified (mixed) farming system	Included with new additional crops (banana, papaya, fodder grasses, melon, chili, sweet potato) and livestock	Included with new additional crops (banana, papaya, fodder grasses, melon, chili, sweet potato) and livestock	Included with additional profitable crops area for banana, papaya, fodder grasses, melon, chili, sweet potato and livestock
b. Household expenditure requirement (Rp000 yr^{-1})	10,205.79 includes unexpected expenses	10,205.79 includes unexpected expenses	8,379.39 not including unexpected expenses
c. Liquidity reserve requirement (Rp000 yr^{-1})	Ignored	Ignored	5,158.55 (cash) and 578.81 (credit) as a reserve for unexpected expenses

All farmers in the study area were organized into water user associations (WUA) likely *subak* in Bali, called with *Sarining Pertiwi*. All farmers are participated actively in monthly WUA meetings and agricultural extension and trainings. Each farm-household operated mixed-farming activities based on the groundwater irrigation system. Accordingly, the system was socially acceptable. The groundwater irrigation system in the study area, with permissible pump debit by 8.547 L s^{-1} was very helpful and useful in increasing the local farmers' income. This is indicated by net cash flow plus liquidity value of reserve cash and credit by Rp9,372,440 per year from the SIFS model or a 259.8 % improvement from the optimal result of the CIFS model. It means it is economically viable.

The mixed-farm management practices based on groundwater irrigation system were consistent with household endowment, recognized and understood by indigenous community, and relevant to the needs of small farmers. Local farmer practices mixed-farming in order to maximize their on-farm income under the groundwater limit.

The optimal level of cattle reared from the SIFS model was about 1,244.14 kg yr^{-1} (or 4.066 units of cattle with the average weight by 306 kg). In this case, the level of cattle is expressed in kilograms in order to determine the matrix coefficient according to activity of feeding it under the several assumptions. For example, how much feed are required and how much manure can be produced by each 100 kilogram live weight of cattle. The level is more than 643.8 kg yr^{-1} that conforms to optimal manure required by 4.71 t yr^{-1} for a 0.556 ha effective area (or 8.471 $t{\bullet}ha^{-1}{\bullet}yr^{-1}$) by assuming each 100 kg live weight of cattle produces manure by 2 kg d^{-1}. It is very important to increase farmer income and to supply organic fertilizer in the form of animal manure. A few farmers still carried out fishing activities to diversify household income. Accordingly, the mixed-farming system practiced by farmers was culturally and technically appropriate and economically profitable.

Risk management is a vital aspect in evaluating sustainability of a farming system. Household expenditure requirement is important for a small farmer. The maximum net cash flow plus liquidity value of reserve cash and credit is usually pursued after household consumption requirement is reached. This is the familiar characteristic of risk-averse farmer with a safety-first behavior (Saragih 1989). Consequently, liquidity reserve requirements are incorporated into the model to reflect the change in the levels of liquidity required due to the relative risk of various activities.

CONCLUSIONS AND IMPLICATIONS

By LP analysis, local farmers in the study area were optimal in resources allocation indicated by the optimal solution from the CIFS model. But, the model can not fulfill the sustainable agricultural criteria. By simultaneous adjustments, the CIFS model can be transformed into the SIFS model to express the sustainable irrigated FSD at the household level. To achieve it, the farmers should be able to apply: the groundwater less than or equal to 8.547 L s^{-1}, the organic fertilizer from manure more than or equal to 5 $t{\bullet}ha^{-1}{\bullet}yr^{-1}$, the mixed-farming system and crop rotation, the minimum household expenditure, and the water price by Rp1,218.29 m^{-3} into the model.

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