OPTIMIZATION OF FARMING SYSTEM TOWARDS SUSTAINABLE AGRICULTURE IN NORTH COASTAL PLAIN, BALI

(Optimisasi Sistem Usaha Tani untuk Pertanian Berkelanjutan di Kawasan Pesisir Bali Utara)

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Abstract

Intensive farming system development (FSD) on poor fertile soil with limited water source can lead to trade-off between economic benefit in the short run and environmental problems in the long run. As environmental degradation increases and inefficient in resources allocation, farming system will become unsustainable. This study aims to optimize irrigated farming system model and to assess its sustainability. By using linear programming analysis, local farmer in north coastal plain of Bali was optimal in resources allocation indicated from optimal solution of conventional farming system model which conforms to observed behavior. By several adjustments, conventional farming system model can be extended to sustainable farming system model. It is found that the sustainable farming system is better than the conventional farming system. Since all components and indicators of sustainability were considered into model and all criteria of sustainability were fulfilled by optimal results, the extended farming system model also guarantees that irrigated farming system development at household level will become sustainable. To make the sustainable farming system at household level, the farmer should be able to allocate the groundwater less than or equal to 8.547 L/s, to add the organic fertilizer from manure more than or equal to 5 t/ha/yr, to continue the mixed-farming system and crops rotation, to consider minimum household expenditure, and to put the sustainable value in the use of water in approximately Rp1,218.29/CM into effect. The sustainable farming system model generated from this study passed validated process. Thus, it can be contributed to scientific development. Also, its results can become best management practices by local farmers on their farms.

Keywords: optimal, farming system, sustainable

Abstrak

Pengembangan sistem usahatani secara intensif pada lahan kurang subur dengan sumberdaya air yang terbatas dapat mengarah pada trade-off antara manfaat ekonomi dalam jangka pendek dan permasalahan lingkungan dalam jangka panjang. Akibat degradasi lingkungan yang meningkat dan alokasi sumberdaya yang tidak efisien, sistem usahatani akan tidak berlanjut. Studi ini bertujuan untuk mengoptimalkan model sistem usahatani beririgasi dan menilai keberlanjutannya. Dengan menggunakan analisis programasi linier, petani di kawasan pesisir Bali bagian Utara telah optimal dalam alokasi sumberdaya yang diindikasikan oleh pencapaian solusi optimal pada model sistem usahatani konvensional yang mencerminkan kondisi kenyataan. Dengan berbagai penyesuaian, *model sistem usahatani konvensional dapat diperluas menjadi model sistem usahatani berkelanjutan. Diperoleh bahwa sistem usahatani berkelanjutan lebih baik ketimbang sistem usahatani konvensional. Karena semua komponen dan indikator keberlanjutan telah dipertimbangkan dalam model dan semua kriteria keberlanjutan telah tercapai dalam solusi optimal, maka model sistem usahatani yang telah diperluas tersebut juga menjamin bahwa pengembangan sistem usahatani beririgasi pada level rumah-tangga akan dapat berkelanjutan. Agar sistem usahatani di tingkat rumah-tangga dapat berlanjut, petani seharusnya menggunakan air tanah sebesar atau kurang dari 8,547 L/dt, menambah pupuk organik dari pupuk kandang minimal sebesar 5 t/ha/th, meneruskan sistem usahatani campuran dan rotasi tanaman, tetap mempertimbangkan pengeluaran minimum rumah-tangga, dan bersedia membayar harga air sebesar Rp1.218,29/m3. Model sistem usahatani berkelanjutan yang dihasilkan dari studi ini telah melalui proses validasi. Dengan demikian, hasil tersebut dapat dikontribusikan untuk pengembangan ilmu pengetahuan di bidang pertanian. Juga, hasil tersebut dapat dijadikan pilihan praktek manajemen oleh petani dalam usahataninya.*

Kata kunci: optimal, sistem usahatani, berkelanjutan.

INTRODUCTION

To form a modern and an efficient agriculture was being the vision of Indonesian's agricultural development in 2020. 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). On the other hand, Fagi (Sugino, 2003) introduced two key issues for agricultural development, namely 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 remarks to the "Green Revolution" that only focus on how to produce large quantities of food for the current year (Brady, 1990). 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, for example, in the Sustainable Development of Irrigated Agriculture in Buleleng and Karangasem (SDIABKA) project can lead to trade-off between economic benefits in the short run and environmental damages, especially soil fertility degradation in the long run. The expansion of cultivated land produced severe erosion problems (Barbier in Small, 2003), whereas, unregulated farming practices have caused critical soil erosion (Saragih, 1989). The excessive erosion has reduced soil quality, then caused rapid reduction in land productivity or even made the land unsuitable for agriculture (Saragih, 1989; Lal *et al*, 1990). On the other hand, only 3.6 million cubic metres (12 %) of groundwater flowing might be remained and recommended annually (Project Management Unit, 1995) to support mixed-farming system in the SDIABKA project area. Depletion of groundwater resource was due to high abstarction (ADB, 1998). These phenomena have adversely jeopardized agricultural production in the long run. It means that as environmental degradation increases, agriculture will eventually become unsustainable (Sugino and Hutagaol, 2004). Thus, best management practices must be considered in FSD. Moreover, to realize sustainable farming system, economic as well as environmental costs must be taken into account (Berbel and Gomez-Limon, 1999; Small, 2003). Accordingly, agricultural development is not only pursuing the economic efficiency but also achieving its long term sustainability.

The SDIABKA project, constructed 39 schemes of groundwater irrigation system, is an attempt to achieve the optimal and sustainable use of resources for irrigated FSD in north coastal plain, Bali. But, in reality, mixed-farming system was still conventionally operated by local farmer. The indicators are: (1) water pricing was just based on operation and maintenance costs and it did not reflect the sustainable value in the use of water. In addition, irrigation was fully subsidized by the project. Consequently, it could make farmer used groundwater inefficiently, (2) the use of organic fertilizer was not based on the soil erosion level and the soil nutrient management, (3) integrated pest management was not fully be considered, and (4) reserve cash and credit was not be considered as response to risks.

Objectives of Study

This study aims to analyze the optimization of groundwater irrigation-based farming system at household level in eastern part of north coastal plain, Bali by using linear programming analysis and then to assess its sustainability

Literature Review

Sustainable agricultural is seen as a holistic farming system which is economically viable, ecologically sound and friendly, socially just equitable and acceptable, and culturally and technically appropriate (SEARCA, 1995). 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). Previously, Virmani and Eswaran (Maji, 1991) suggest criteria for evaluating the sustainability of agricultural system. These include 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 & de Los Reyes (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. Linear programming models can be used to test the on-farm efficiency of resource use (Standen, 1972).

METHOD

One of 39 schemes of irrigated farming system with well code of TMB-59 at SDIABKA project area (Figure 1) was purposively chosen as a representative study area since farm modeling with a linear programming analysis has never conducted by independent party. A good performance of irrigated mixed-farming system development at household level in TMB-59 also became an important reason.

Primary and secondary data based on indicators of sustainable agriculture were used to specify parameters of the model. The primary data were collected from 42 farmers in TMB-59 which were chosen by census procedure while secondary data were gathered from appropriate sources. A linear programming package program, named BLPX88 (Eastern Software Product, Inc., 1984) was used to solve the constrained optimization problem for irrigated farming system at household level in the study area. According to Timmer (Soekartawi, 1996), the arithmetic mean of the observed parameters can be used in linear programming analysis.

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

Maximize:

$$z = c_1x_1 + ... + c_jx_j + ... + c_nx_n + c_lx_l$$

Subject to:

$$a_{11}x_1 + ... + a_{1j}x_j + ... + a_{1n}x_n \leq b_1$$

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

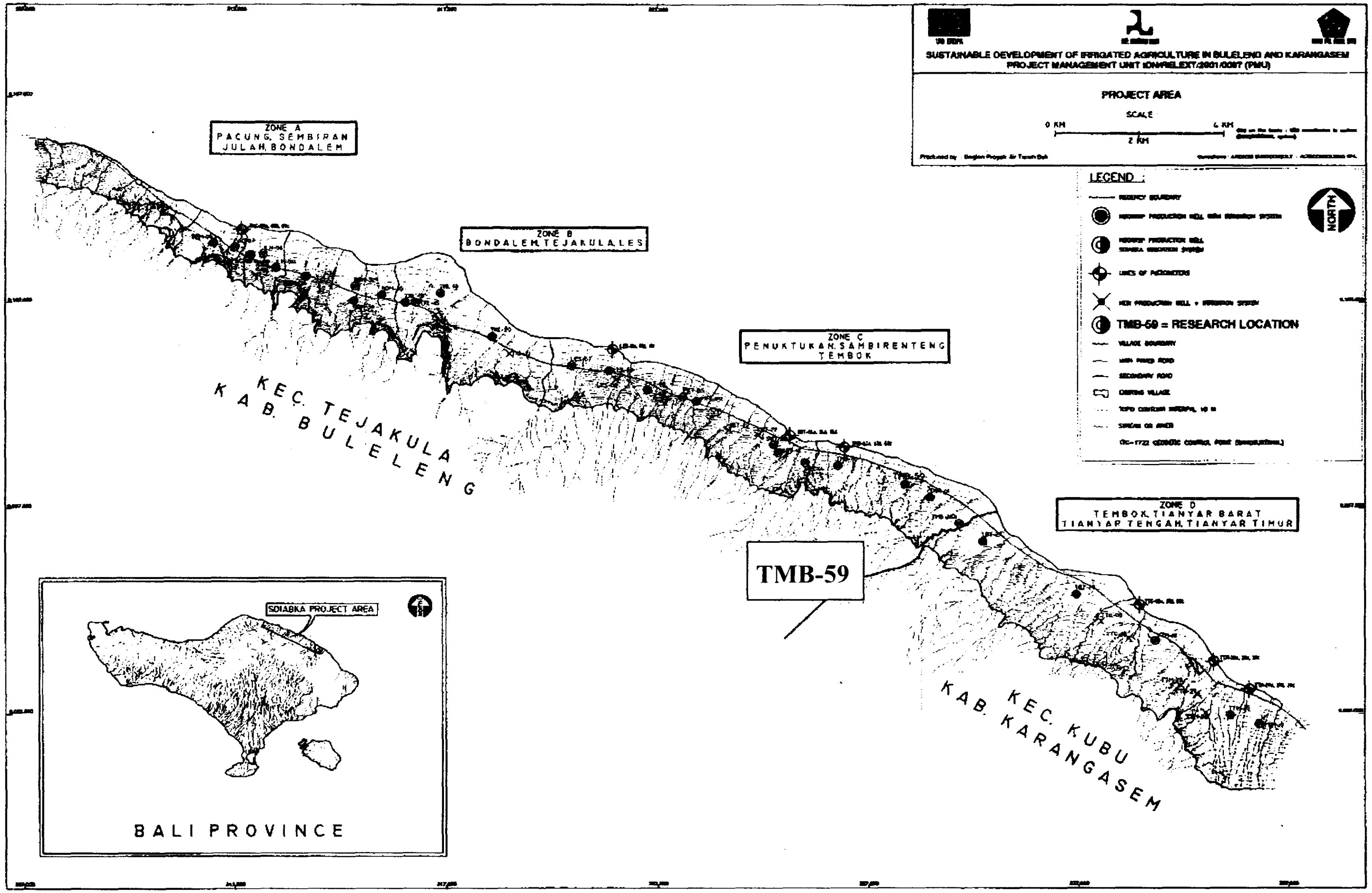

Figure 1.
Research location, TMB-59 in Tembok Village

where z is the objective function, $c_l x_l$; x_j's are the activity alternatives; b_i's are the constraints: requirements (>), restrictions (<), and equalities (=); 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} is the level at which cash decreases (>0) or increases (<0) by choices in production, consumption, marketing and finance including reservation of cash; a_{cr} is the level at which credit decreases (>0) or increases (<0) by choices in production, consumption, marketing, and finance including reservation of credit; a_{lj} is the addition to (<0) or satisfaction of (>0) liquidity by a unit of x_j; all 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. The objective function in this study is to maximize net cash flow plus liquidity value of reserve cash and credit for irrigated mixed-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.

RESULTS AND DISCUSSIONS

The Conventional Farming System Model

The conventional farming system model that reflects existing condition was specified as a representative farm-household unit 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, and 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.

Confidence interval was utilized to test the null hypothesis that the optimal values of the model does not differ significantly from actual values or survey mean. Organizational and performance output measures of the model must fall within defensible confidence interval as estimated through a survey. Acceptance of such null hypothesis means that the model conforms to observation.

Table 2 provides the valuation results by using sustainability criteria to the validated model. Based on the table, the farming system model which expressed existing condition can be categorized as a conventional farming system since its optimal levels were failed to fulfilled all the sustainable criteria. In this case, groundwater abstraction in Dry Season 1 is actually greater than the permissible groundwater abstraction by equal or less than 1,054.9 CM/DS2. This condition will lead to the groundwater source can be depleted. In addition, groundwater pricing still very simple and was 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 response to financial risk.

Table 1. The optimal levels from conventional farming system model and observed mean from a survey

Activity	Conventional Farming System	Survey Mean	Survey 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 crops (ha)	.4395	.446	.361	.298 - .595
- Mango (trees)	25.00	25.76	20.43	17.33 – 34.19
- Coconut (trees)	17.6	17.6	23.29	7.98 – 27.20
- Cashew (trees)	8	8	10.78	3.55 – 12.45
- Palmyra palm for sap (trees)	1.9	1.9	3.27	.89 - .2.91
- Palmyra palm for fruit (trees)	3.1	3.1	4.17	2.02 – 4.59
Annual crops (ha)	.0809	.0995	.0702	.0701 - .1284
Seasonal crops (ha)	.0988	.124	.1239	.0732 - .1754
Cattle 3 (100 weight kgs)	6.26	6.62	4.91	4.07 – 9.77
4. Organic fertilizer app. (t/yr)	2.995	2.89	1.89	2.11 – 3.67
5. Inorganic input application:				
- Urea 1 (kgs)	29.22	37.40	25.81	26.25 – 48.05
Urea 2 (kgs)	84.26	144.22	90.32	107.36 – 181.88
Urea 3 (kgs)	32.83	32.66	29.46	20.51 – 44.82
- SP36 1 (kgs)	13.93	16.95	18.05	9.50 – 24.39
SP36 2 (kgs)	18.42	25.3	14.79	19.19 – 31.40
SP36 3 (kgs)	-	-	-	-
- KCl 1 (kgs)	17.69	23.00	20.55	14.53 – 31.48
KCl 2 (kgs)	27.63	37.95	22.19	28.79 – 47.11
KCl 3 (kgs)	-	-	-	0
- NPK 1 (kgs)	21.08	27.97	20.67	19.44 – 36.49
NPK 2 (kgs)	8.32	8.296	21.54	-.59 – 17.18
NPK 3 (kgs)	3.89	3.095	11.31	-1.57 – 7.76
- ZA (kgs)	3.08	3.12	8.97	-.58 – 6.82
- KNO_3 (kgs)	.88	1.00	2.93	-.65 – 2.65
- Dolomit (kgs)	344.71	430.15	313.19	300.95 – 559.35
- Power growth stimulator (l)	.74	.86	3.54	-.60 – 2.32
- Furadan (kgs)	.044	.044	.095	.005 - .084
- Diazinon (l)	.345	.35	.55	.114 - .568
6. Household expenditure				
- Season 1 (000Rp)	3,401.93	3,401.93	1,280.76	2873.5 – 3930.3
- Season 2 (000Rp)	3,401.93	3,401.93	1,280.76	2873.5 – 3930.3
- Season 3 (000Rp)	3,401.93	3,401.93	1,280.76	2873.5 – 3930.3
7. Buy groundwater				
- Season 1 (CM)	676.10	786.68	548.11	560.56 – 1012.8
- Season 2 (CM)	1,099.74	1,167.94	724.03	869.26 – 1466.6
- Season 3 (CM)	79.61	210.96	138.4	153.84 – 268.04
9. Reserve cash (000Rp)	-	-	-	-
10. Reserve credit (000Rp)	-	-	-	-
11. Borrowed informal fund				
- Season 1 (000Rp)	315.12	315.12	1,272.79	-130.4 – 760.7
- Season 2 (000Rp)	103.93	103.93	565.69	-94.1 – 301.9
- Season 3 (000Rp)	159.76	159.76	141.42	110.2 – 209.3
12. Fishing (Fisherman)				
- Season 1 (trips)	2.57	2.57	4.98	1.03 – 4.11
- Season 2 (trips)	2.57	2.57	4.98	1.03 – 4.11
13. FMET				
- Season 1 (times)	10.42	10.42	4.09	8.74 – 12.12
- Season 2 (times)	6.33	6.33	2.08	5.47 – 7.19
- Season 3 (times)	8.14	8.14	2.67	7.04 – 9.25

Table 2. Valuation results to the validated model

Management practices	Sustainability indicators	Sustainability requirement	Analysis results [a]	Achievement of sustainability criteria
Irrigation Management	Groundwater quality	Non saline	Good quality	Safety for domestic & agriculture uses
	Groundwater extraction	≤ 1,054.9 CM/DS1	= 676.1 CM/DS1	Ecologically sound
		≤ 1,054.9 CM/DS2	=1,099.74 CM/DS2	Environmentally degrading
		≤ 87.91 CM/RS	=76.61 CM/RS	Ecologically sound
	Pump debit	< 25 l/s [b]	= 14.4 l/sec	Technically appropriate
	Irrigation subsidy	No subsidy	= Rp997.46/yr	Economically inefficient
	Groundwater pricing	Sustainable value in the use of water (Rp1,218.29/CM) [c]	Rp300/CM	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/yr [d]	2.036 t/ha/yr	Very light
	Organic fertilizer use	> 5 t/ha/yr [e]	5.386 t/ha/yr	Environmentally non-degrading
	Land suitability	CEC>16me/100g	CEC 5-16 me/100g	S2 and S3 [f]
Mixed Farming System	Cropping pattern	Multiple cropping , Choosing profitable crops and adding its area	Conducted	Technically appropriate and Economically profitable
	Livestock (cattle)	> 386.1 kgs life weight/yr	= 838 kgs life weight/yr	Related to organic fertilizer requirement
	Fishing	= 5.14 trips/yr	= 5.14 trips/yr	
Integrated Pest Management	Cropping pattern	Crops rotation	Conducted	Ecologically sound & friendly
Financial Risk Management	Household expenditure req.	≥ Rp11,736,660/yr	= Rp10,205.79	Financial risk
	Inflation level over period 1997 to 2006	15 percent	Ignored	Financial risk
	Liquidity reserve requirement	≥Rp3,357,270/yr	Ignored	Financial risk
Human and Social Capital	Family labor distribution	≤ 46.39 man-days/month	32.39–48.64 man-days/month	Socially acceptable
Management	Membership in organization	As a member in TUG	Effective member in TUG of Sarining Pertiwi	
	FMET	= 24.89 md/yr	= 24.89 md/yr	
Goal	Objective function	Maximize net cash flow plus liquidity reserve of cash and credit	Rp3,606,850/yr (without liquidity management)	(Economically viable but involve financial risk)

[a] Bold letter indicated optimal level from conventional farming system model
[b] Arif and Pusposutardjo, (1994)
[c] Budiasa, *et al.* (2006)
[d] Greenland and Lal (Nuarsa, 1991)
[e] Based on the research finding by Sukartaatmadja *et al.* (2003)
[f] 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)

Accordingly, environmental, economical and risk assessment criteria were not fully considered in this farming system model.

Changes of Conventional to Sustainable Farming System Model

Several adjustments aimed to reform the conventional farming system model, then, to find sustainable farming system model at household level. These adjustments were: (1) replacing the existing groundwater use by the permissible abstraction; (2) adjusting ground-water pricing to reflect sustainable value in the use of water, then, impose it into model; (3) eliminating the irrigation subsidy; (4) considering inflation effect and cash and credit reservation as an attempt to response to risks; (5) considering minimum use of organic fertilizer from manure as an attempt to prevent critical soil erosion; (6) keeping mixed-farming and crops rotation as a pest control strategy as well as choosing better crops and adding their area constraints to maximize the objective function subject to their limited groundwater supplies; (7) replacing the existing labor use by the potential labor supply; and (8) improving farm technologies based on trial results conducted by Project Management Unit (2005).

Table 3 provided a summary information to prove the sustainable farming system model. The model was developed based on all the best management practices and indicators of sustainability. Optimal results yielded from the model fulfilled all the requirements and criteria of sustainable agriculture.

In terms of irrigation management, the model introduced appropriate irrigation technology with pump debit by 8.547 l/s. Pusposutardjo (1997) indicated that ground water pump irrigation system of shallow and medium-depth ($\leq$25 l/s), is an appropriaate irrigation technology for small farmer since it increased the local farmers' welfare. The use of groundwater by 1,853.89 CM/yr, which is still below the groundwater limit by 2,197.71 CM/yr, also less than the actual groundwater use by 2,165.58 CM/yr, indicated ecologically sound. The use of groundwater in this model was economically efficient, indicated by imposing water price by Rp1,218.29/CM into model and eliminating irrigation subsidy by Rp997,460/yr from the model.

In response to soil erosion, the model requested the use of organic fertilizer greater than 5 t/ha/yr. The optimal use of organic fertilizer generated from the model was 8.471 t/ha/yr that more than its requirement. The use of organic fertilizer especially from composted manure was very important for effectiveness of inorganic fertilizer use. This indicated that soil nutrient management was environmentally non-degrading.

Local farmer carried out multi-storied-cropping-pattern in order to maximize their on-farm income under the groundwater limit. The optimal number of cattle reared by 1,244.14 kilograms life weight per year, was more than 645.2 kilograms life weight per year than can fulfill all manure required by 4.71 t/yr for .556 ha farm-land (8.471 t/ha/yr) by assuming each 100 kilograms life weight produces 2 kilograms manure per day. It was very important to increase farmer income and to supply organic fertilizer in form of animal manure. A few farmers still carried out fishing activity to diversify household income. Mixed-farming system conducted by farmer was technically appropriate and economically profitable.

An appropriate crop rotation can be very effective in controlling pests, diseases, and weeds, as well as offer numerous advantages in soil structure, fertility, and erosion management. It also indicates that innovative farming system under the sustainable farming system model was environmentally sound.

Risks management is a vital aspect in evaluating sustainability of 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 model to reflect the change in the levels of liquidity required due to the relative risk of various activities.

Each farmer attempts to maximize his net cash flow plus liquidity value of reserve cash and credit after minimum household expenditure reached. To achieve this goal, the farm-household attempted to allocate the potential family labor supply to various activities in on-farm, off-farm and non farm. To increase their knowledge and experiences in agriculture technology, the farmer actively involved in farmer meeting and agricultural

Table 3. Summary of optimal results, best management practices, indicators and criteria for sustainable farming system model at household level

Best management practices	Indicators	Requirement	Analysis Results [a]	Sustainability criteria
Irrigation management	Groundwater quality	Non saline	Good quality	Good and safety for domestic & agriculture use
	Extraction	≤ 2,197.71 CM/yr	= 1,853.89 CM/yr	Ecologically sound
	Pump debit	< 25 l/s [b]	= 8.547 l/s	Technically appropriate
	Irrigation subsidy	No subsidy	Subsidy Rp0.00	Economically efficient & autonomous
	Groundwater pricing	Sustainable value in the use [c]	Rp1,218.29/CM	Economically efficient & autonomous
Land (soil nutrient) management	Soil fertility	Fertile soil	Sandy loam texture, CEC 5-16 me/100g, C-org < 2%)	Poor fertile soil
	Soil erosion	<14.4 t/ha/yr [d]	2.036 t/ha/yr	Very light
	Organic fertilizer use	> 5 t/ha/yr [e]	8.471 t/ha/yr	Environmentally non-degrading
	Land suitability	CEC>16me/100g	CEC 5-16 me/100g	S2 and S3 [f]
Mixed farming system	Cropping pattern	Multiple cropping, Choosing profitable crops and adding its area	Conducted	Technically appropriate and Economically profitable
	Livestock (cattle)	> 386.1 kgs life weight/yr	1,244.14 kgs life weight/yr	Related to organic fertilizer requirement
	Fishing	= 5.14 trips/yr	= 5.14 trips/yr	
Integrated pest management	Cropping pattern	Crops rotation	Conducted	Ecologically sound & friendly
Financial risk management	Household expenditure req.	≥ Rp8,379,390/yr	= Rp8,379,390/yr	Risk-averse farmer
	Inflation level over period 1997 to 2006	15 percent	Input prices and household expenditure increase by 15 %	
	Liquidity reserve requirement	≥Rp3,357,270/yr	= Rp5,158,550/yr (cash) = Rp578,810/yr (informal credit)	
Human and social capital	Family labor distribution	≤ 46.39 man-days/ month	37.89-46.39 man-days/ month	Socially acceptable
Management	Membership in organization	As a member in TUG	Effective member in TUG of Sarining Pertiwi	
	FMET	= 24.89 md/yr	= 24.89 md/yr	
Goal	Objective function	Maximize net cash flow plus liquidity value of reserve cash and credit	Rp9,372,440/yr	Economically viable

[a] Bold letter indicated optimal level from sustainable farming system model
[b] Arif and Pusposutardjo, 1994
[c] Budiasa, *et al.* (2006)
[d] Greenland and Lal (Nuarsa, 1991)
[e] Based on the research finding by Sukartaatmadja *et al.* (2003)
[f] 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)

extension and training (FMET). The farmer was also member of tube well user group (TUG) of Sarining Pertiwi. The TUG has awig-awig (norms) to regulate its member related to various activities in irrigated farming system development. The existing of the institution as a form of social capital is vital to institutionalize irrigated farming system development in order to fulfill socially acceptable criteria.

CONCLUSION

Local farmers in the study area were optimal in resources allocation for irrigated farming system development at household level. It is indicated by optimal solution yielded from conventional farming system model which conformed to observed behavior. However, some optimal levels from the model failed to fulfill all criteria of sustainable agriculture. By the several adjustments based on all indicators and components of sustainability, the conventional farming system model can be extended to express the sustainable farming system at household level. Based on the optimal results, the sustainable farming system model is better than conventional farming system model. Also, the sustainable farming system model guarantees that irrigated farming system development at household level will become sustainable since all criteria of sustainable agriculture were fulfilled by optimal solutions. Economically, the value of net cash flow plus liquidity value of reserve cash and credit generated from sustainable farming system model increased by 259.8 percent.

To make farmer at coastal plain is actually to be autonomous, aware of water resource scarcity, and economically efficient in water resource allocation; the recommendations are (1) the farmer should use groundwater less than or equal to permissible groundwater limit, (2) the government should stop irrigation subsidy, and (3) the farmer willing to pay full cost of water. Due to poor fertile soil and intensive cropping system in the study area, then, to improve soil fertility, land productivity, and soil ability to hold water and nutrients, and to protect soil against erosion at the level more than 2.036 tons/ha/year can be achieved by adding organic matter at greater than or equal to 5 tons/ha/year. To improve net cash flow plus liquidity value of reserve cash and credit or to minimize economic loss in household farming system, local farmers must conduct farm technology improvement. Also, in order to develop sustainable farming system, mixed farming system and irrigation management should be continued to counter business risk such as failure in farm production and prices fluctuation. Liquidity management and household expenditure requirement should be continuously considered by farmer to decline financial risk.

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