

**SUSTAINABLE IRRIGATED FARMING SYSTEM DEVELOPMENT UNDER THE
SMALL LAND HOLDING CONDITION IN NORTH COASTAL PLAIN, BALI**

**(DEVELOPPEMENT D'UN SYSTEME DURABLE D'AGRICULTURE IRRIGUEE DANS
LES CAS DE PETITS TERRAINS SUR LES PLAINES COTIERES DU NORD DE BALI)**

Dr. I Wayan Budiasa, SP, MP[†]

ABSTRACT

Intensive farming system 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 will affect unsustainable farming system. This study aims to develop sustainable irrigated farming system (SIFS) model at household level in north coastal plain, Bali.

Survey data from 42 farmers in representative scheme and secondary data from any 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 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 less than or equal to 8.547 l/s, the organic fertilizer from manure more than or equal to 5 t/ha/yr, the mixed-farming system and crops rotation, the minimum household expenditure, and the water price by Rp1,218.29/CM into model.

KEYWORDS: Sustainable, Irrigated Farming System, Small Land Holding

[†] Lecturer at Faculty of Agriculture (Agribusiness Dept.) University of Udayana, Campus Bukit Jimbaran, Badung 80361 – BALI, Indonesia, Phone/Fax Nos: +62 - 361 - 223544, 702801, Email address: wba_sosek_unud@yahoo.com

INTRODUCTION

Intensive farming system on poor fertile 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 SDIABKA 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 SDIABKA 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 aims to develop the SIFS model at household level in north coastal plain, Bali. The specific objective is to analyze the optimization of groundwater irrigation-based farming system at household level by using linear programming analysis and then 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 [Soekartawi, 1996]),.

BLPX₈₈ (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 household level can be illustrated as follows:

$$\text{Maximize: } z = c_1x_1 + \dots + c_jx_j + \dots + c_nx_n + c_lx_l$$

$$\text{subject to: } a_{i1}x_1 + \dots + a_{ij}x_j + \dots + a_{in}x_n \leq b_i$$

$$a_{cal}x_1 + \dots + a_{caj}x_j + \dots + a_{can}x_n + a_{cal}x_l = \text{cash}$$

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

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

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

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 subtraction 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.

RESULT AND DISCUSSION

The CIFS model was specified as a representative existing condition under observation. Confidence interval was utilized to test null hypothesis: optimal values of the model does not differ significantly from survey mean. Acceptance of such null hypothesis means that the model conforms to observation. The CIFS is indicated by the actual groundwater usage that is greater than permissible usage. Water pricing was very simple that only based on the OM costs. Whereas, the simple water cost was fully subsidized by project. The subsidy and simply water pricing tend to decrease irrigation efficiency.

Some adjustments aimed to reform the CIFS model to find the SIFS model, i.e.: (1) replacing actual groundwater abstraction by the permissible usage; (2) adjusting simply 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 response 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.

SEARCA (1995) defined sustainable agriculture as a holistic farming system that are economically viable, ecologically sound, socially just, and culturally and technically appropriate. Table 1 provides the changes of optimal levels generated from the SIFS model due to simultaneous adjustments at the CIFS model. The former was seemingly more ecologically sound than the later, indicated by the optimal levels of organic fertilizer application 8.471 t/ha/yr (>5 t/ha/yr). Organic fertilizer usage more than or equal to 5 t/ha/yr is to prevent soil erosion in the study area increases from 2.036 t/ha/yr (Budiasa and Mega, 2007). This result has good relation with erosion level by 2.04 t/ha/yr from experimental result with mean gradient slope of 9 percent and cow manure dosage by 5 t/ha/yr (Sukartaatmadja *et al*, 2003). The groundwater and inorganic fertilizers usages tend to decrease from 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).

All farmers in the study area were organized into water user association (WUA) likely *subak* in Bali, called with *Sarining Pertiwi*. All farmers are actively participated in monthly WUA meeting and agricultural extension and training. 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 was very helpful and useful in increasing the local farmers' welfare. 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 259.8 percent improved from the optimal result of CIFS model). It means economically viable.

Table 1. The change of optimal levels resulted from the SIFS model due to simultaneous adjustments at the CIFS model

Sustainability Criteria by SEARCA (1995)	Survey Mean	Models	
		CIFS	SIFS
Economically viable, efficient, autonomous			
a. The value of objective function (Rp000/yr)	-	3,606.85	9,372.44
b. Irrigation subsidy (Rp000/yr)	997.46	997.46	0.00
c. Groundwater price (Rp000/CM)	300.00	300.00	1,218.29
d. Inflation by 15 %	Ignored	Ignored	Included
Ecologically sound and friendly			
a. Groundwater limit	2,165.58 CM/yr	1,855.44 CM/yr	1,853.89 CM/yr
b. Composition of organic fertilizer (OF) and inorganic fertilizer (IOF) use related to Soil Nutrient Management.	OF = 5.190 > 5 t/ha/yr IOF = 1,422.58 kgs/ha/yr	OF = 5.386 > 5 t/ha/yr IOF = 1,088.92 kgs/ha/yr	OF = 8.471 > 5 t/ha/yr IOF = 1,297.46 kgs/ha/yr
c. Integrated pest management	Crops rotation	Crops rotation	Crops rotation
Socially acceptable			
	FMET ^a , institutionalized in WUA	FMET ^a , institutionalized in WUA	FMET ^a , institutionalized in WUA
Technically & culturally appropriate			
	Irrigation technology (14.4 l/s < 25 l/s) without farm technology improvement	Irrigation technology (14.4 l/s < 25 l/s) without farm technology improvement	Irrigation technology (8.547 l/s < 25 l/s) with farm technology improvement

^a FMET = farmer meeting, extension, and training (participatory irrigated farming system development)

Mixed-farm management practices based on groundwater irrigation system was consistent with household endowment, recognized and understood by indigenous community, and relevant to the needs of small farmers. Accordingly, mixed-farming system conducted by farmer was culturally and technically appropriate and economically profitable.

CONCLUSION AND IMPLICATION

By LP analysis, local farmers in the study area were optimal in resources allocation indicated by optimal solution from the CIFS model. But, the model can't fulfill all sustainable criteria of farming system. By simultaneous adjustments, the CIFS model can

be extended to the SIFS model to express the sustainable irrigated FSD at household level. To achieve it, the farmers should be able to apply: the groundwater less than or equal to 8.547 l/s, the organic fertilizer from manure more than or equal to 5 t/ha/yr, the mixed-farming system and crops rotation, the minimum household expenditure, and the water price by Rp1,218.29/CM into model.

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RESUME ET CONCLUSIONS

Le système d'agriculture intensive peut mener à un compromis entre des bénéfices économiques dans le court-terme et des problèmes environnementaux dans le long-terme. La dégradation croissante de l'environnement et l'inefficacité dans l'allocation des ressources agricoles auront un impact sur la non-viabilité des systèmes agricoles. Cette étude tente de développer un modèle de système durable d'agriculture irriguée (SDAI) à l'échelle du foyer d'habitation dans les plaines côtières du Nord de Bali.

Les données de l'étude proviennent de 42 agriculteurs dans un schéma représentatif dans le cadre du projet de Développement Durable d'Agriculture Irriguée à Buleleng et Karangasem (2003-2006) et les données secondaires de toutes les sources ont été utilisées pour spécifier les paramètres du modèle. L'analyse de la programmation linéaire (PL) a été utilisée pour résoudre le problème d'optimisation limitée. Cette étude a commencé par l'analyse de l'optimisation du système d'agriculture basé sur l'irrigation souterraine au niveau du foyer d'habitation, et a été poursuivie par l'évaluation de la durabilité du système. La fonction de l'objectif de cette analyse est de maximiser le flux net de trésorerie y compris la valeur de liquidité des réserves de trésorerie et du crédit pour le système d'agriculture irriguée au niveau du foyer d'habitation sujet aux contraintes imposées par le terrain, la disponibilité de la main-d'œuvre, l'abstraction des nappes phréatiques, le stock d'engrais et de pesticides organiques et/ou non-organiques, le stock de cultures pérennes, le stock de graines de cultures annuelles et saisonnières, le stock d'animaux d'élevage et d'aliments, la consommation du ménage et les dépenses imprévues, etc.

En utilisant l'analyse de programmation linéaire, un petit agriculteur avec un terrain de 0,556 hectares est déjà efficace dans l'allocation des ressources agricoles indiquées par la solution optimale de système conventionnel d'agriculture irriguée (SCAI), conformément au comportement observé. La condition conventionnelle signifie que le modèle n'a pas réussi à s'adapter à tous les critères durables. Avec des ajustements simultanés, le modèle conventionnel SCAI peut ensuite être amené à devenir un modèle de SDAI pour exprimer le développement du système durable d'agriculture irriguée à l'échelle du foyer d'habitation. Les ajustements sont (1) le remplacement de l'abstraction réelle des nappes phréatiques par l'usage autorisé ; (2) l'ajustement d'une tarification simple du prix de l'eau avec une tarification complète ; (3) l'élimination des subventions d'irrigation du crédit de départ de la réserve de liquidité ; (4) la prise en compte de l'effet de l'inflation et des réserves de trésorerie et de crédit pour prévenir les risques ; (5) envisager une utilisation minimale des engrais organiques ; (6) la conservation d'une agriculture mixte et des rotations de cultures comme stratégie de lutte antiparasitaire ; (7) le remplacement de l'utilisation de la main-d'œuvre existante par la main-d'œuvre potentielle ; et (8) l'amélioration des technologies agricoles.

Le modèle SDAI semble plus écologique que le modèle SCAI, d'après les indicateurs suivants : (a) l'application d'engrais organiques en quantité 8,741 t/ha/an (> 5t/ha/an) ; et (b) l'utilisation des nappes phréatiques et des engrais non-organiques a tendance à diminuer par rapport à la moyenne réelle. L'application d'engrais non-organiques dans une quantité inférieure à la moyenne réelle indique que le modèle suit le concept de faible apport externe pour une agriculture durable (FAEAD).

Tous les agriculteurs de la zone d'étude sont déjà organisés en Association d'Utilisateurs d'Eau (AUE). Ils participent activement dans les réunions mensuelles de l'AUE, l'extension agricole et les formations agricoles. Chaque ménage d'agriculteur

opère des activités d'agriculture mixte basé sur un système d'irrigation d'eau souterraine. Ainsi, le système est accepté socialement.

Le système d'irrigation souterraine dans la zone étudiée, avec un débit à la pompe de 8,547 l/s apporte une aide considérable et est très utile pour améliorer le bien-être des agriculteurs locaux. L'atteinte de la fonction de l'objectif à hauteur de Rp9 372 440 par an par le modèle SDAI le démontre (soit 259,8 pour cent d'amélioration par rapport au résultat optimal du modèle SCAI). Cela signifie que ce modèle est économiquement viable.

Le système d'agriculture mixte conduit par un agriculteur est culturellement et techniquement approprié et économiquement profitable. En conséquence, en modélant l'agriculture, le développement du système d'agriculture irriguée dans les cas de petites propriétés dans la région du projet de Développement Durable d'Agriculture Irriguée à Buleleng et Karangasem sera durable car économiquement viable, respectueux de l'environnement, accepté socialement et culturellement et techniquement approprié.