An Optimization Approach for Farmer Selection and Allocation in Agricultural Supply Chain

Natchanon Benjamanukul
Graduate School of Management and Innovation
King Mongkut's University of Technology Thonburi, Bangkok, Thailand
Tel: (+66) 0-2470-9776, Email: tvx1150@hotmail.com

Udom Janjarassuk
Department of Industrial Engineering, Faculty of Engineering
King Mongkut' s Institute of Technology Ladkrabang, Bangkok, Thailand
Tel: (+66) 0-2329-8339 ext. 228, Email: kjudom@gmail.com

Kanokporn Rienkhemaniyom †
Graduate School of Management and Innovation
King Mongkut's University of Technology Thonburi, Bangkok, Thailand
Tel: (+66) 0-2470-9776, Email: kanokporn.rie@gmail.com

Abstract. For an agricultural supply chain, in which a contract farming system has been applied, farmer's income depends on yield and quality of crop, which can be varied among individual farmers, and also purchasing price from a collector. However, considering only income may not ensure the sustainability of farmer in term of economic return dimension. Costs associated with cultivation and post-harvest activities must also be considered. This study presents a mathematical model supporting farmer selection and allocation decisions for an agricultural supply chain, which consists of a set of farmers, a consolidating plant, and a distributor. The model is formulated as a multi-criteria mixed integer linear programming and solved it in two phases. The first phase is the screening process, where farmers' performance is evaluated against the desired net income level. Farmers who pass the evaluation criteria will be selected for Phase 2. For those who do not pass the criteria, they need further technical assistance or plant other crops. In phase 2, crop allocation decision is determined under multiple objectives. The proposed model is illustrated with an actual application of a lettuce head cultivation in a highland area in Northern Thailand.

Keywords: Agricultural supply chain, Optimization, Farmer selection and allocation, Sustainability

1. INTRODUCTION

In recent years, an interest on the application of operation research for agricultural supply chains has emerged (Ahumada and Villalobos, 2011). Agriculture is highly important, especially for highland areas in Northern Thailand, where small-scale producers (farmers) live in rural area and their income mainly come from working in agriculture. Like small-scale farmers in other rural areas, the problems weakening agricultural development for small-scale farmers are the lack of access market, poor productivity levels, lack of access to finance, increased cost of quality inputs, such as fertilizers, sprouts, high costs of production and climate changes (Repar et al., 2013). Contract farming models have been advocated as one of the means to sustain agricultural development by enhancing backward and forward market linkages in agricultural production (Mwambi et al., 2014).

The main underlying motivation for developing this study is to emphasize on the small-scale farmers' welfare under contract farming system, in which the profit and loss of small-scale farmers are highly depend on purchasing price and farmers' capability in agricultural production.

The remaining of this paper is constructed as follows. Section 2 presents a brief review of contract farming system and the studies related to optimization approach in agricultural supply chain planning and the measure of farmers' economic return sustainability. Section 3, we present the framework and formulation of an optimization approach to support farmer selection and allocation decision. Section 4 provides illustrative example, which draws from a real problem of a lettuce head cultivation in a highland area in Northern Thailand. Section 5 presents conclusions and recommendations from the study.

2. LITERATURE REVIEW

Contract Farming (CF) is an agreement between a farmer and a purchaser established prior to the growing season for a specific quantity, quality and date of delivery of an agricultural output at a price fixed in advance (Setboonsarng, 2008). According to Eaton and Shepherd (2001), there are five models of contract farming, namely nucleus, informal, centralized, multipartite, and intermediary model. Interested readers are referred to Mwambi et al. (2014) for more details of those models. According to Mwambi et al. (2014), contract farming affects farmers' welfare in several reasons. First, contract that has interlinked services such as financial credit, technical advice, training, market information, which focus on enhancing smallholder productivity would increase marketed surplus. Contract farming acts as an institutional solution to market failures. Second, contract farming is a strategy for fostering farmers' participation in restructured markets and value chains, therefore increasing and stabilizing farmers' incomes. Third, contract that allows prices of outputs and the terms to be decided in advance may reduce risks due to price fluctuation, hence providing incentive mechanisms for farmers to allocate resources efficiently.

Farmer's welfare can be considered as one of the sustainability components. Smit and Smithers (1993) have provided the meaning of sustainable agriculture in several dimensions and scales, as shown in Table 1.

Table 1. Meaning of Sustainable Agriculture by Dimensions and Scales (Smit and Smithers, 1993)

Dimension	Scale		
	Micro	Meso	Macro
Natural resource base	Field level soil fertility, moisture	Agro-ecosystems, regional land capability	Continental water and land resources, global climate
Crop production	Field yield, management	Regional production, land use	Global food supplies
Economic return	Farm level production costs, viability	Regional economy, value of production	Trade marketing, policies
Rural community	Farm level tenure, family involvement	Rural community size and function, access to food	Global poverty, hunger, equity

Although agreement of price and output quantity have been made in advance, farmer's income still depends on yield and quality of crop, which can be varied among individual farmers. In this paper, we focus on the relationship between crop production and economic return at micro level based on the meaning of sustainable agriculture in Smit and Smithers (1993) (as shown in Table 1). The economic return at farm level depends upon yield, product quality, price, and cost.

Optimization has been applied for solving agricultural supply chain planning problems. Economic return of farmer has been considered as one of the objective. For example, Ahumada and Villalobos (2011) proposed an operational model for determining the harvest and distribution planning of perishable agricultural products under consideration of product quality and cost of additional labor and transportation. The model objective is to maximize financial return of the producers. Ahumada et al. (2012) presented a two-stage stochastic tactical planning for production and distribution of fresh agricultural products under uncertainty of weather condition and demand. The objective is to maximize the expected profit of the producer. Pitakpongjaroen (2015) developed a multi-criteria mathematical model to solve agricultural production plans considering food security, decent income and minimizing the environmental impacts from chemicals use. Recio et al. (2002) developed a decision support system for farm planning. The authors formulated the problem as a mixed-integer linear programming model. The model provides the decisions of annual planning, that is, when to perform each field task and using what resources. Piewthongngam et al. (2009) applied mathematical modelling support sugar supply chain planning. Mathematical programming is formulated to determine planting dates, cultivars and harvesting period subjected to different cane yields, which estimated using the crop grown model and data from the growers' database. The objective is to maximize overall sugar production under the limitations of a mill's capacity and cane grown area. Li and Zabinsky (2011) developed a two-stage stochastic programming model (SP) and a chance-constrained programming (CCP) to solve a supplier selection considering uncertainty of demand and supplier capacity in an agricultural business. Both models considered multiple objectives, including minimizing total purchasing and shipping cost, maximizing the probability of satisfying demand and supplier capacity, minimizing the total number of chosen suppliers, maximizing the quality of received plants, and minimizing the late deliveries. The models aimed to balance a small number of suppliers with the risk of unmet demand.

This paper presents an optimization approach to support farmer selection and allocation decisions, which is an extension of Benjamanukul (2016) by including the cost of outbound transportation (both fixed cost and variable cost) from a farmer's site to a collection center. The main contributions of this paper are as follows: first, we consider the net income of farmers instead of income or revenue to ensure that the sustainability, in terms of economic return has been emphasized. In addition, the screening results can be used as a feedback to the collector to take an accountability of the economic welfare of their suppliers. Finally, the multi-criteria objective problem simultaneously considers an economic aspect of both farmers and a collector as well as an environmental aspect of natural resource consumption.

3. METHODOLOGY

An agricultural supply chain considered in this study consists of farmers, who do cultivation of agricultural products, a collecting center, who purchases products from farmers and provides technical assistance, a distributor, who purchases products from a collector and distributes them to retailers and then customers, as shown in Figure 2. Figure 3 presents the key factors affect farmer's revenue and expense as well as a collector's revenue and expense.

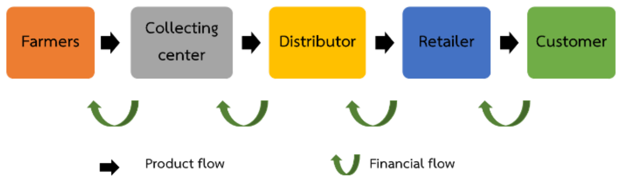

Figure 2. A typology of an agricultural supply chain

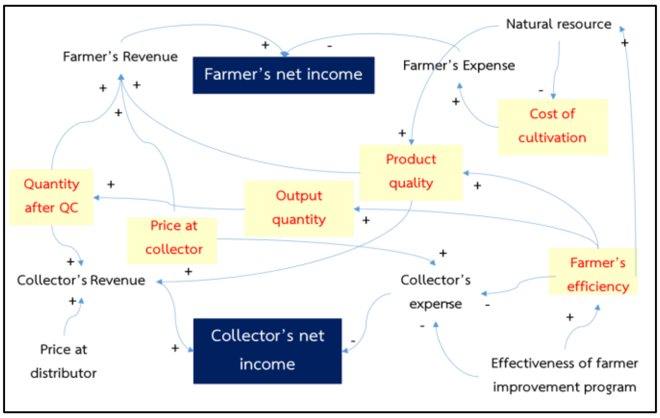

Figure 3. Key drivers of farmer's and collector's net income

From Figure 3, purchasing price at a collector, market price, farmer's efficiency in terms of quantity (yield or productivity) and quality (quality levels or grades) are considered as model parameters. Followings are additional assumptions considered in the model:

1. Land conditions of all farmers are indifferent.
2. Parameters, such as yield, efficiency, water used factor, are collected from historical data over a long period of time. It can be used for a cultivation planning for the same period.
3. Farmer receives revenue after a collector has completed a packing process.
4. Cost incurred at farmers includes cultivation cost and outbound transportation cost, while cost incurred at a collector includes purchasing cost and processing cost. Transportation cost is included in the sales price to the distributor.
5. The model is formulated as a deterministic single-crop planning.

3.1 Notation

A notation of the proposed optimization model for selection and allocation decisions are as follows:

Sets:

F set of farmers
T set of periods
G set of quality levels

Parameters:

w_g weight of product at quality level g (kg/unit)
pc_g price upon agreement that a collector buys product from farmers (baht/kg)
pm_g market price of product (baht/kg)
cf unit cost of cultivation incurred at farmer level (baht/unit)
cc unit operation cost incurred at a collector level (baht/kg)
d_t forecasted demand at period t (kg)
cap_{ft} capacity of farmer f in period t (units)
θ_{ft} yield or productivity of farmer f in period t (%)
β_{gft} % of product grade g of farmer f in period t (%)
δ failure rate at a collecting center (%)
wt_{ft} water usage factor of farmer f in period t
h minimum quantity allocated to farmer (units)
cvt_f variable transportation cost incurred to farmer f (Baht/shipment)
cft_f fixed transportation cost incurred to farmer f (Baht)
$shipCap_f$ shipping capacity (kg/shipment)

Decision Variables:

X_{ft} binary variable = 1 if farmer f is selected in period t, = 0 otherwise
Q_{ft} Cultivation quota allocated to farmer f in period t (units)
$noTrip_{ft}$ Number of shipment of farmer f in period t (trips)

3.2 Phase I: Screening process

In this phase, each farmer f will be evaluated weather their average productivity (yield) and average efficiency are sufficient such that a net income from cultivation, which is the difference between revenue and cost is greater than or equal to the desired income level.

For each farmer, an average revenue incurred under an allocated quantity of Q units can be determined as Equation (1), where $\bar{\theta}$ and $\bar{\beta}$ represent the average value of yield and the average percentage of product at each quality level, respectively.

$$Revenue = \sum_g^G w_g \left(pc_g * Q * \overline{\theta * \beta_g}\right) \quad (1)$$

For each farmer, the cultivation and transportation cost incurred at an allocated quantity of Q units can be determined as Equation (2).

$$Cost = (cf * Q) + [cft + (cvt * noTrip)] \quad (2)$$

where $noTrip = \sum_g^G w_g \left(Q * \overline{\theta * \beta_g}\right)/shipCap$

A farmer will pass the screening process if the net income or the difference between revenue and cost exceeds the desired income level. A farmer that passes the screening phase will be as a candidate in the next phase. On the other hand, for those who fail the screening phase, it indicates that a collector must take accountability to enhance their technical capability such that they earn positive income from the cultivation activity.

3.3 Phase II: Selection and allocation

From Phase I, farmers who pass the screening process are the candidates for the selection and allocation phase.

Objective functions:
The first objective function is to maximize the total farmers' net income, as shown in Equation (3):

$$Farmers' \ net \ income = \sum_g^G w_g \left(\sum_f^F \sum_t^T pc_g Q_{ft}\theta_{ft}\beta_{gft}\right) - \left(\sum_f^F \sum_t^T cf Q_{ft}\right) - \left(\sum_f^F \sum_t^T cft_f X_{ft}\right) - \left(\sum_f^F \sum_t^T cvt_f noTtrip_{ft}\right) \quad (3)$$

The second objective function is to maximize total profit of a collector, as shown in Equation (4). The first term represents sales revenue, while the second term represents product cost and operating cost, respectively.

$$Collector's \ net \ income = \left[\sum_g^G w_g \left(\sum_f^F \sum_t^T pm_g (1-\delta) Q_{ft}\theta_{ft}\beta_{gft}\right)\right] - \left[\sum_g^G w_g \left(pc_g + cc\right)\left(\sum_f^F \sum_t^T Q_{ft}\theta_{ft}\beta_{gft}\right)\right] \quad (4)$$

The third objective function is to minimize the water usage

$$minimize \quad \sum_f^F \sum_t^T wt_{ft} \, Q_{ft} \quad (5)$$

Constraints:

$$d_t \le \sum_g^G w_g \left(\sum_f^F Q_{ft}\theta_{ft}\beta_{gft}\right) \le maxd_t \quad \forall \ t \in T \quad (6)$$

$$hX_{ft} \le \theta_{ft} \le cap_{ft} \, X_{ft} \quad \forall f \in F, \ t \in T \quad (7)$$

$$\sum_t^T X_{ft_t} \ge 1 \quad \forall f \in F \quad (8)$$

$$X_{ft} \in \{0,1\}, \quad Q_{ft} \ge 0, integer \quad \forall f \in F, \ t \in T \quad (9)$$

Equation (6) represents a demand constraint. The quantity of sprouts allocated to farmers in each period must be sufficient to meet planned demand but it cannot exceed the maximum allowance in order to avoid the over-supply. Equation (7) indicates the minimum requirement of an allocation quantity and also ensures that the quantity cannot exceed the available land. Equation (8) ensures that, for a planning horizon, a farmer must be selected at least once to ensure that a farmer will earn income from the cultivation. If this constraint is omitted, the model will select only high performance farmers. Equation (9) represents non-negativity and binary variables.

To solve the proposed multi-criteria problem, we apply non-preemptive goal programming technique. The model is coded and solved using LINGO 16.0. Additional set, parameters and decision variables are as follows:

Set:

Z	Set of objective or goal

Parameters:

$Ideal_z$	Ideal value of objective z
$Target_z$	Target value of objective z
wg_z	Numerical weight of objective z
Obj_z	Value of objective z

Decision Variables:

$dpos_z$	Positive deviation from target value of goal z
$dneg_z$	Negative deviation from target value of goal z

Hence, the preemptive goal programming model for the selection and allocation problem can be formulated as follows:

$$min = wg_1 dneg_1 + wg_2 dneg_2 + wg_3 dpos_3 \quad (10)$$

Subject to the following goal constraints:

$$(Obj_z/Ideal_z) + dneg_z - dpos_z = 1 \quad \forall \ z \in Z \quad (11)$$

$$\sum_z^Z wg_z = 1 \quad (12)$$

$$0 \le dneg_z \le 1 \quad \forall \ z \in Z \quad (13)$$

$$0 \le dpos_z \le 1 \quad \forall \ z \in Z \quad (14)$$

$$0 \le wg_z \le 1 \quad \forall \ z \in Z \quad (15)$$

and real constraints in Equations (6) to (9).

4. RESULTS AND DISCUSSIONS

In order to illustrative the applicable of the proposed model. We test the proposed model with a lettuce head cultivation area, which is located in Northern Thailand considering 10 farmers, 6 periods, 2 quality levels. Criteria weights are obtained by interviewing a manager at a collector center. Weights for the three objectives are 0.5, 0.2, and 0.3, respectively. Table 2 presents the productivity of farmers at each period. Tables 3 and 4 show efficiency of farmers to produce lettuce head at each quality level. Suppose the average unit cost of cultivation incurred at a farmer level is 1 Baht, whereas the average unit cost at a collector level is 1.5 Baht. There is 15% of waste at a collection center. The average unit prices that a collector agrees to purchase grade 1 and grade 2 products from farmers are 17 Baht/kg and 15 Baht/kg, respectively. Market price for lettuce head grade 1 is 23 Baht/kg, while the price for grade 2 is 20 Baht/kg. There is a policy that the total production cannot exceed 20% of the demand. Additionally, the minimum allocated quantity is 30 trays, which contains 6,000 sprouts (1 tray contains 200 sprouts). Note that every 8 sprouts require an area of 1 sq.m. Fixed transportation cost is 500 Baht per period, variable transportation cost per shipment for each farmer is different, which depends on the distance from farm to a collection center. In this paper, we set a variable transportation cost of farmers as a random parameter, which is uniformly distributed with the minimum and maximum value of 200 and 300 Baht per trip. Finally, shipping capacity of farmers to ship their products to a collector is about 1 ton per trip.

In Phase 1, a screening process, we assume that the desired net income of a farmer is zero. This assumption seems unrealistic, but it is for illustrative purpose. Therefore, we can check whether a farmer's productivity and efficiency factors are sufficient to achieve the desired net income level. Otherwise, that farmer(s) should not be selected for the cultivation.

For example, Farmer 0001 has an average productivity of 0.9, while the average percentage of grade 1 and grade 2 are 0.9 and 0.1, respectively. Therefore, the average revenue at any *Q* units is [0.4*17*Q*0.9*0.9]+[0.3*15*Q*0.9*0.1] = 5.913Q Baht, while the cultivation cost is Q Baht and the transportation cost is 500+0.212[(0.4*Q*0.9*0.9)+(0.3*Q*0.9*0.1)] = 500+1.074Q Baht. At the given productivity and efficiency factors, if the minimum allocation quantity (Q) such that this farmer will earn a positive net income is 104 sprouts or 1 tray. Therefore, Farmer 0001 will be a candidate for the next phase.

Let consider Farmer 0010, who has an average productivity of 0.09, while the average percentage of grade 1 and grade 2 are 0.09 and 0.91, respectively. The average revenue is [0.4*17*Q*0.09*0.09]+[0.3*15*Q*0.09*0.91] = 0.424Q Baht, while the cultivation cost is Q and transportation cost is 500+0.259[(0.4*Q*0.09*0.09)+(0.3*Q*0.09*0.91)] or 500+1.007Q Baht. Obviously, the unit cost is greater than the revenue, in other words, the net income of this farmer is negative. Hence, the collector should not allocate quota to this farmer. Farmer 0010 does not pass the screening phase. It implies that the collector shall enhance the farmer's capability such that the productivity or percentage of high quality product are improved.

Table 5 presents the parameters of farmers' variable transportation cost per trip, productivity (%), and efficiency in producing product at each quality level (%). The last column of Table 5 shows the net income subjected to Q, assuming that the desired net income is zero (for an illustrative purpose), the result shows that Farmers 0009 and 0010 do not pass the screening process as the unit cost is higher than the revenue. It implies that a collector may need to enhance technical capability for these farmers to ensure that they can make positive net income from cultivation or they should be assigned to cultivate other type of crops. For instance, given that the percentage of grade1 and grade 2 products remains unchanged, if the productivity value of farmer 0009 can be increased from 0.11 to 0.16 and the productivity value of farmer 0010 can be improved from 0.09 to 0.22, their net incomes will be positive.

After complete the screening phase, next we solve the selection and allocation model for the remaining 8 farmers. Table 6 provides ideal values for each objective function. They are obtained by solving a single objective problem for each objective, while ignoring other objective. The ideal values of total farmers' net income, a collector's net income, and water used are 455,719.2 Baht, 35,470.54 Baht, and 167,966.1 m^3, respectively. We also observe that, for a farmers' net income objective model, the model tends to allocate higher amount of cultivating quantity to the farmers who has higher yield parameter values. For a collector's net income objective model, the model gives higher priority to the farmers who has higher efficiency in producing high quality level of lettuce head. This is because the higher quality level of lettuce head results in a higher margin from market price, which increases the collector's net income.

The last row of Table 6 is the objective values obtained from a goal programming approach. We use the ideal value as the target value for each goal. The total farmers' profit is 444,113.3 Baht, which is 2.55% lower than its ideal value. The collector's profit is 31,685.3 Baht, which is 10.67% lower than its ideal value. The water used is 194,999 m^3, which is 16.09% higher than its ideal value. Table 7 provides the optimal allocation quantity assigned to Farmer 0001-0008. The farmers who has higher productivity and efficiency to produce high quality lettuce head will receive higher allocate quantity.

Table 2: Productivity of farmers at each period

Farmer\Period	1	2	3	4	5	6

0001	0.83	0.84	0.89	0.92	0.99	0.93
0002	0.87	0.95	0.98	0.93	0.93	0.85
0003	0.66	0.69	0.63	0.63	0.67	0.79
0004	0.70	0.77	0.66	0.69	0.77	0.62
0005	0.44	0.43	0.52	0.43	0.59	0.44
0006	0.58	0.43	0.42	0.47	0.46	0.50
0007	0.37	0.26	0.25	0.39	0.33	0.21
0008	0.39	0.25	0.27	0.31	0.26	0.36
0009	0.01	0.08	0.16	0.16	0.05	0.17
0010	0.10	0.08	0.01	0.13	0.15	0.10

Table 3: Efficiency of farmers to produce lettuce head grade 1

Farmer\Period	1	2	3	4	5	6
0001	0.89	0.99	0.86	0.92	0.83	0.91
0002	0.17	0.17	0.04	0.07	0.16	0.17
0003	0.84	0.91	1.00	0.89	0.97	0.80
0004	0.06	0.15	0.09	0.18	0.04	0.19
0005	0.82	0.97	0.84	0.86	0.97	0.81
0006	0.07	0.15	0.05	0.04	0.04	0.08
0007	0.97	0.92	0.87	0.93	0.88	0.96
0008	0.04	0.15	0.13	0.18	0.05	0.12
0009	0.99	0.98	0.98	0.98	0.82	0.93
0010	0.15	0.05	0.08	0.08	0.12	0.04

Table 4: Efficiency of farmers to produce lettuce head grade 2

Farmer\Period	1	2	3	4	5	6
0001	0.11	0.01	0.14	0.08	0.17	0.09
0002	0.83	0.83	0.96	0.93	0.84	0.83
0003	0.16	0.09	0.00	0.11	0.03	0.20
0004	0.94	0.85	0.91	0.82	0.96	0.81
0005	0.18	0.03	0.16	0.14	0.03	0.19
0006	0.93	0.85	0.95	0.96	0.96	0.92
0007	0.03	0.08	0.13	0.07	0.12	0.04
0008	0.96	0.85	0.87	0.82	0.95	0.88
0009	0.01	0.02	0.02	0.02	0.18	0.07
0010	0.85	0.95	0.92	0.92	0.88	0.96

Table 5: Farmers' variable transportation cost, productivity, and efficiency assuming that desired net income level = 0

Farmer	Variable transportation cost	Average yield	Average efficiency to produce grade 1	Average efficiency to produce grade 2	Net income
0001	212	0.90	0.90	0.10	-500+4.839Q
0002	235	0.92	0.13	0.87	-500+3.347Q
0003	266	0.68	0.90	0.10	-500+3.397Q
0004	286	0.70	0.12	0.88	-500+2.281Q
0005	234	0.47	0.87	0.13	-500+2.013Q
0006	227	0.47	0.07	0.93	-500+1.158Q
0007	280	0.30	0.92	0.08	-500+0.952Q
0008	229	0.31	0.11	0.89	-500+0.451Q
0009	268	0.11	0.95	0.05	-500-0.276Q
0010	259	0.09	0.09	0.91	-500-0.584Q

Table 6: Selection and allocation decisions from a farmers' profit maximization

Model	Total farmers' profit	Collector's profit	Water used
Average farmers' profit maximization	**455,719.2**	33,034.27	219,981
Collector's profit maximization	442,203.4	**35,470.54**	245,610.6
Water used minimization	386,555.6	26,599.62	**167,966.1**
GP model	**444,113.3 (2.55%)**	**31,685.3 (10.67%)**	**194,999 (16.09%)**

Table 7: Allocation quantity (number of trays) from a GP model

Farmer\Period	Period						Total	Profit
	1	2	3	4	5	6		
0001	32	32	31	32	32	32	191	184,786
0002	32	0	30	32	32	0	126	83,723
0003	32	32	32	32	32	32	192	129,635
0004	0	32	0	0	0	0	32	16,935
0005	0	0	0	0	0	32	32	10,843
0006	0	0	30	0	0	0	30	5,205
0007	32	0	0	0	0	0	32	9,148
0008	0	0	0	0	0	30	30	3,839
0009	0	0	0	0	0	0	0	-
0010	0	0	0	0	0	0	0	-

5. CONCLUSION AND RECOMMENDATION

This paper presents an optimization approach to support selection and allocation problem in an agricultural supply chain. The contributions of this work are in two-fold. First, we proposed a screening process to ensure that farmers who will be selected for the cultivation have sufficient capability, determined by yield and efficiency factors, such that their net incomes would meet the desired target. Second, the screening results can be used as a feedback to a decision maker, which refers to the collector in this paper, to take an accountability of the economic welfare of their suppliers. Finally, the multi-criteria objective problem considered economic return of farmers and a collector, with the minimal used of water, simultaneously.

Since the proposed model is developed under deterministic assumption, future work may incorporate uncertainty of some parameters (e.g., demand, cost, yield, percentage of product at each quality level) to make the problem more realistic. Then, the robust planning could be applied, which similar to the study in Li and Zabinsky (2011). Multiple crops planning could also be a potential extension. In addition, it is interesting to evaluate the impact of different purchasing schemes to the net income of farmers as well as a collector. In this paper, we assume that farmer will receive income after a collector has completed a packing process, which means that wastes in the process is a hidden cost to farmer.

REFERENCES

Ahumada, O., and Villalobos, J. R. (2011). Operational model for planning the harvest and distribution of perishable agricultural products. *International Journal of Production Economics*, **133**(2), 677-687.

Ahumada, O., Villalobos, J. R., and Mason, A. N. (2012). Tactical planning of the production and distribution of fresh agricultural products under uncertainty. *Agricultural Systems*, **112**, 17-26.

Benjamanukul, N. (2016). Model for farmer selection and allocation in agricultural supply chain. Master Thesis. Graduate School of Management and Innovation, King Mongkut's University of Technology Thonburi.

Li, L., and Zabinsky, Z. B. (2011). Incorporating uncertainty into a supplier selection problem. *International Journal of Production Economics*, **134**(2), 344-356.

Mwambi., M.M., Oduol, J., Mshenga, P., and Saidi, M. (2016) "Does contract farming improve smallholder income? The case of avocado farmers in Kenya", *Journal of Agribusiness in Developing and Emerging Economies*, **6** (1), 2 – 20.

Ortuño, M. T., and Vitoriano, B. (2011). A goal programming approach for farm planning with resources dimensionality. *Annals of operations research*, **190**(1), 181-199.

Piewthongngam, K., Pathumnakul, S., and Setthanan, K. (2009). Application of crop growth simulation and mathematical modeling to supply chain management in the Thai sugar industry. *Agricultural Systems*, **102**(1), 58-66.

Pitakpongjaroen, T., (2015). Multiple goal production systems of highland farm household in Chiang Mai province. *Khon Kaen Agricultural Journal*, **43**(1), 69-75.

Recio, B., Rubio, F., and Criado, J. A. (2003). A decision support system for farm planning using AgriSupport II. *Decision Support Systems*, **36**(2), 189-203.

Repar, L., Onakuse, S., and Bogue, J. (2013). Contract Farming as Business Model for Sustainable Rural-Urban Supply Chains: Sincere Efforts or Just Profit?.

Smit, B., and Smithers, J. (1993). Sustainable agriculture: interpretations, analyses and prospects. *Canadian Journal of Regional Science*, **16**(3), 499-524.