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Development of Seeding and Planting Scheduling Algorithms for Contract Farming of Organic Vegetable with Multi Seeding and Planting Center

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Abstract. Organic vegetables are perishable products with special characteristics because its shelf life is influenced by product characteristics, environmental conditions and production time. Customer only buys fresh organic vegetables because its price is more expensive than the non-organic ones. The scheduling of seeding and planting process becomes the most important thing for organic vegetables producer. They must ensure the right time and good condition in organic vegetables consumer delivery. An organic vegetable products company is implementing a contract farming system. They have some Planting and Seeding Centers (PSCs) across several cities. PSC is an organization which cooperate with farmers in contract farming. The functions of PSC are to seed, distributing the seeding result to farmers, packing vegetables form farmers and shipping vegetables to customers. Farmers will plant the seeds received from PSC based on a schedule given by PSC. This research will develop an algorithm of seeding and planting scheduling by PSC and farmers. There are several types of vegetables: vegetables with seeding, vegetables without seeding, planted inside green house, and planted in an open field. PSC and farmers are determined by the nearest distance to customers, the availability of green houses and open fields. The purpose of this algorithm is to optimize PSC seeding and planting scheduling, so we can minimize production costs (seeding, planting, packing and distribution costs) and maximize profits.

1. Introduction

The concept of efficiency, optimum and high profit value is important for industry. This is could be obtained by balancing between supply and demand [1], where could be done by proper planning and production scheduling. Indonesia is agricultural country, where agricultural business is still a major business and has a large market share. An increasingly agribusiness sector is organic vegetables.

Vegetables as perishable products or agricultural industrial products are highly specialized product (easily damaged) that characteristics by environmental conditions and timing [2].



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Other factors that affect the quantity and quality of organic vegetable production are environmental factors such as weather, sunlight and soil conditions [1]. Complexity factor of organic vegetable products need to be controlled to meet the customer needed. This is one of the reasons for the importance of planning and production scheduling of perishable products as well as their distribution to achieve a balance between supply and demand from the agricultural industry.

Manufactures of perishable products especially Indonesian organic vegetables apply contract farming concept in producing and distributing vegetables. The company works together by contracts with the vegetable farmers who will be given seeds based on demand from customers. The company will choose which farmers will plant and when the plantation should be done. The decision of farmers selection and planting time greatly affects the fulfillment of customer demand both quantity and product quality [3]. Farmers will receive revenue from the company according to their harvesting. Vegetables from farmers will be packed and distributed to customers by the company. So that the costs incurred by the company are the costs of the farmer's salary, packing costs and distribution costs [1]. In a greenhouse, farmers can plant two types of vegetables with mixed cropping method [4]. This aims to maximize available land use. To facilitate the process of nursery, packing and distribution then the company made a Planting and Seeding Centers (PSCs) across several cities. The goal is to minimize operating costs and to obtain maximum profit. This research will develop a planning algorithm for PSC seeding and planting scheduling from a vegetable supplier company.

2. Contract Farming

Contract farming is a method to increase production and revenue of farmers (farming, fishery, etc). Contract farming has been widely carried out in various countries. It is able to prosper farmers through increased production [5], increase market access and prices [6]. This can affect farmers' revenue [5]. Agribusiness partnership is a business strategy that can be carried out by two or more parties within a certain period. This strategy can provide benefits to all parties. This type of partnership is generally in the form of a vertical coordination that is often followed by a contractual relationship or an agreement [7]. There are many planting methods in contract farming.

Mixed cropping and single cropping are two of the planting methods. Single cropping is a planting method with one type of plant. Mixed cropping is a planting method with various types of plants in an area at the same time. Mixed cropping method is mostly used for vegetables with short planting periods and once cropping (mustard, spinach, kale, cabbage, etc.). Mixed cropping can increase the revenue of farmers [4]. This system was chosen to increase production with various requests and land efficiency. This research will compare the efficiency of land with and without mixed cropping method.

3. Model

This research will develop a model and algorithm of seeding and planting scheduling to obtain the profit of the company. The company produces organic vegetables. They have demand from organic vegetable retailers in several cities everyday. Vegetables are perishable products, so they must be delivered to the customer as soon as possible. They have three PSCs to serve all customers in several cities. The customer will be served by the nearest PSC. The PSC is responsible for seeding, distributing the seeding results to farmers, packing vegetables from farmers and shipping vegetables to customers.

PSC collaborates with farmers by applying a contract farming system. All farmers plant the seeds according to the planting schedule given by the PSC. The illustration of information flow of organic vegetable company can be seen in Figure 1. below.

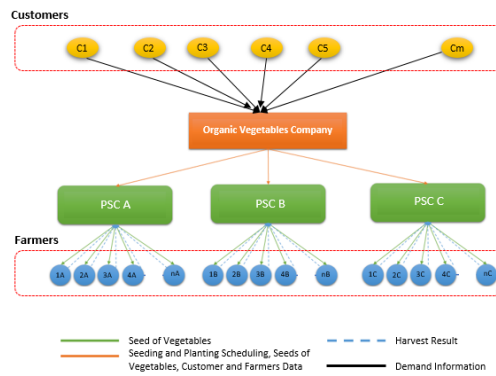


Figure 1. Information Flow Chart of Organic Vegetable Company

All vegetables cropped by the farmers will be purchased by the PSC. Every farmer who joins them must meet the company specifications. The company give Green House and open field with same area and quality. All farmers plant some vegetables. They need different treatment (vegetables with seeding, vegetables without seeding, planted inside green house, and planted in an open field). For seeding, every PSC have two Green House (GH 1 and GH 2). They use tray for seeding in GH. GH used is determined based on seeding time.



Figure 2. Tray for Seeding [8]

Each farmer has two GH (GH 3 and GH 4) and open field. Each GH has two blocks (25 m²/block) and each open field has five blocks (25 m²/block). One block for GH or open field only contain not more than two types of plants. If all contract farming farmers' land is full, then the PSC will rent the land and other farmers to avoid backorder or lost sales. In this research, a linear programming model was refined to schedule seeding and planting time [4] and adjusted to the conditions in the research object. There are several types of vegetables: vegetables with seeding, vegetables without seeding, planted inside green house, and planted in an open field. PSC and farmers are determined by the nearest distance to customers, the availability of green houses and open fields, the productivity and cost aspects.

For scheduling, we use backward scheduling method because the company use make to order system and the vegetables must be delivered as soon as possible. We develop algorithm for seeding and planting scheduling. The algorithm illustrated by Figure 3.

The Notation:

- ACGH : available capacity of green house (m²)
- ACOF : available capacity of open field (m²)
- Fm : farmer m (m = number of farmer)
- St : the amount of seed for seeding in GH PSC period t
- Pt : the amount of seed for planting in GH farmer m period t
- LTSj : lead time or seeding time of vegetable j
- LTPj : lead time or planting time of vegetable j
- RVkt : income earned by PSC k period t
- MCkt : maintenance cost of PSC k period t
- RNkt : rent cost of PSC k period t
- BCKt : backorder cost of PSC k period t
- LSkt : lost sale cost of PSC k period t
- t : period
- i : demand index
- p : productivity (%)
- k : PSC index
- j : vegetable index

The constraints:

- The amount of seed to be planted: consider the land productivity and demand
 $St = Dit \times (100\% + (100\% \times p))$ (1)
- The capacity of green house
 $ACGH \leq 2 \times 25m^2$ (2)
- The capacity of open field
 $ACGOF \leq 5 \times 25m^2$ (3)

The objective function:

$$Maximize: \sum_k \sum_t RV_{kt} - \sum_k \sum_t MC_{kt} - \sum_k \sum_t RN_{kt} - \sum_k \sum_t BC_{kt} - \sum_k \sum_t LS_{kt} \quad (4)$$

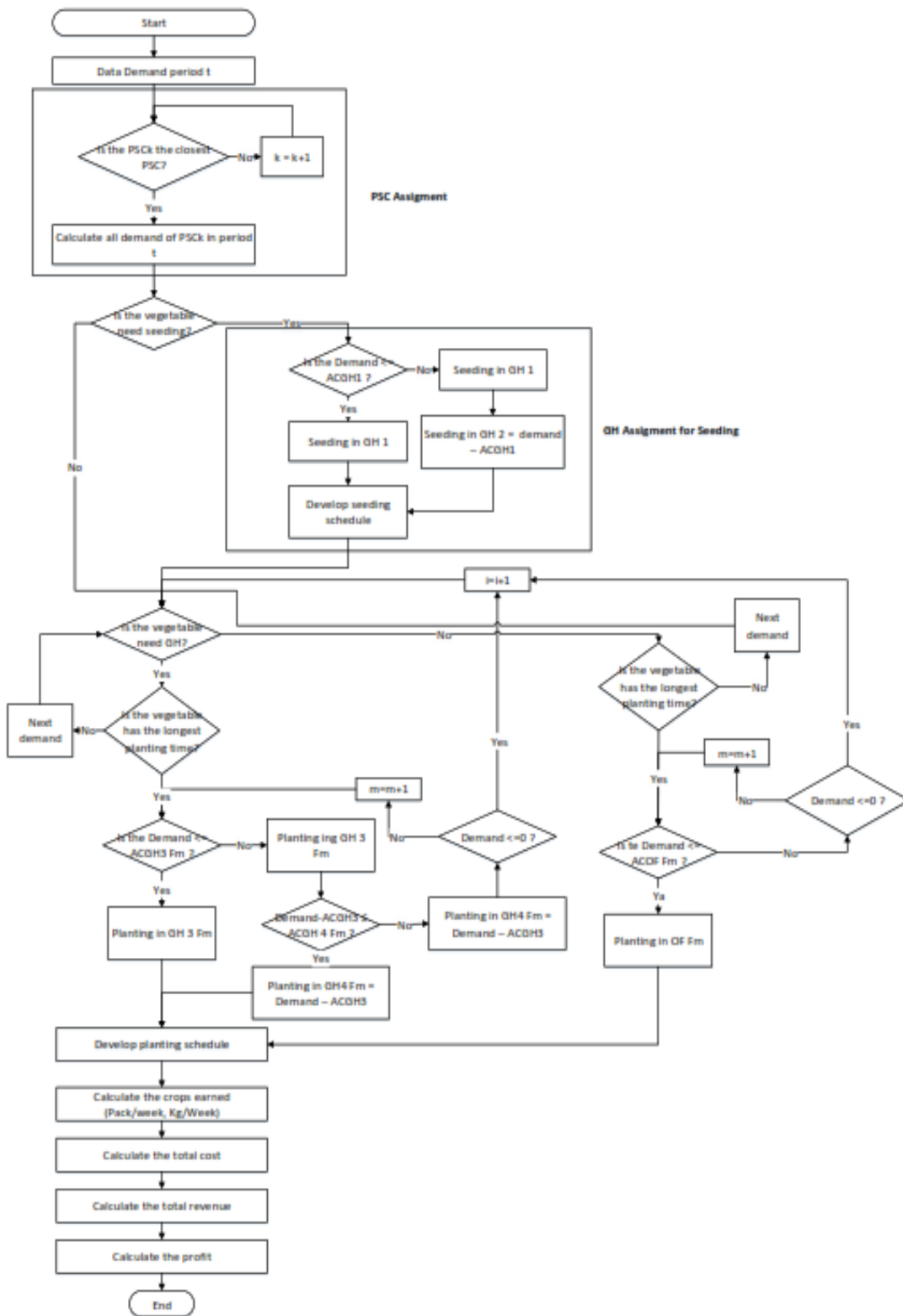


Figure 3. Algorithm of Seeding and Planting Scheduling

4. Numerical Experiment

We try with three PSC (GH 1 and GH 2). Each PSC has four farmers (GH3, GH4). Each farmer plant five vegetable type: mustard caisim, kale, spinach, sweet corn, and chili. Each vegetable has characteristic like in Table 1. Kale and sweet corn do not need seeding process. Chili is not once cropping plant. In one planting of chili, chili can be cropped five times.

Table 1. Characteristic of Five Vegetables

Vegetable	Seeding Time	Planting Time	(Gram/Pack)	Crops Earned		The Capacity per Block	
	Week	Week		(Ton/Ha)	(Kg/m2)	(Kg/Blok)	(Pack/Blok)
Mustard Caisim	2	4	200	20	2	50	250
Kale	0	6	200	15	1.5	37.5	187.5
Spinach	2	4	200	20	2	50	250
Sweet Corn	0	10	1000	27	2.7	67.5	67.5
Chili	4	6	200	15	1.5	37.5	187.5

The data demand in daily, but the seeding and the planting time in weekly. The farmers can plant every day (can disturb another plant to grow), so we calculate the data demand in weekly. Table 2. illustrates the data demand of PSC 1.

Table 2. Weekly Data Demand

PSC 1	Vegetables	September				
		I	II	III	IV	V
Pack	Mustard Caisim	385	373	388	563	109
	Kale	270	272	260	265	85
	Spinach	426	373	235	403	148
	Sweet Corn	191	200	191	237	66
	Chili	205	334	321	323	29
Kg	Mustard Caisim	77	74.6	77.6	112.6	21.8
	Kale	54	54.4	52	53	17
	Spinach	85.2	74.6	47	80.6	29.6
	Sweet Corn	191	200	191	237	66
	Chili	41	66.8	64.2	64.6	5.8

Table 3. Seeding Scheduling of PSC 1

GH	Vegetables	June				July				August				September					
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV		
GH 1	Mustard Caisim	Porel (Kg)							93.17	22.23	93.90	136.25	26.38						
		Total Porel (Kg)							93.17	115.40	209.30	252.38	162.62	26.38					
		Porec (Kg)									93.17	22.23	93.90	136.25	26.38				
	Chili	Porel (Kg)			24.81	18.09	2.47	4.13	3.51										
		Total Porel (Kg)			24.81	42.89	45.36	49.49	53.00	28.19	10.10	7.64	3.51						
		Porec (Kg)							24.81	18.09	2.47	4.13	3.51						
GH 2	Spinach	Porel (Kg)							39.71	90.27	56.87	97.53	35.82						
		Total Porel (Kg)							39.71	129.98	186.85	244.66	190.21	133.34	35.82				
		Porec (Kg)									39.71	90.27	56.87	97.53	35.82				
	Chili	Porel (Kg)			24.81	18.09	2.47	4.13	3.51										
		Total Porel (Kg)			24.81	42.89	45.36	49.49	53.00	28.19	10.10	7.64	3.51						
		Porec (Kg)							24.81	18.09	2.47	4.13	3.51						

Table 4. Planting Scheduling of PSC 1 Farmer 1

GH	Vegetables		June				July				August				September						
			I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	V		
GH 3	Mustard Caisim	Porel (Kg)																			
		Total Porel (Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.80	20.80	20.80	20.80	20.80	0.00	0.00	0.00	0.00	0.00	
		Porec (Kg)														20.80					
	Kale	Porel (Kg)																			
		Total Porel (Kg)	0.00	0.00	0.00	0.00	0.00	0.00	59.40	59.40	59.40	59.40	59.40	59.40	59.40	0.00	0.00	0.00	0.00	0.00	
		Porec (Kg)														59.40					
	Spinach	Porel (Kg)																			
		Total Porel (Kg)																			
		Porec (Kg)																			
		ACGH (m ²)	50.00	50.00	50.00	50.00	50.00	50.00	10.40	10.40	0.00	0.00	0.00	0.00	0.00	50.00	50.00	50.00	50.00	50.00	
	GH 4	Mustard Caisim	Porel (Kg)																		
			Total Porel (Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.90	63.90	63.90	63.90	63.90	0.00	0.00	0.00	0.00	0.00
Porec (Kg)																63.90					
Kale		Porel (Kg)																			
		Total Porel (Kg)																			
		Porec (Kg)																			
Spinach		Porel (Kg)																			
		Total Porel (Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.10	36.10	36.10	36.10	36.10	0.00	0.00	0.00	0.00	0.00	
		Porec (Kg)														36.10					
		ACGH (m ²)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00	50.00	50.00	50.00	
OF		Sweet Corn	Porel (Kg)			210.10															
			Total Porel (Kg)	0.00	0.00	210.10	210.10	210.10	210.10	210.10	210.10	210.10	210.10	210.10	210.10	210.10	0.00	0.00	0.00	0.00	0.00
	Porec (Kg)															210.10					
	Chili	Porel (Kg)																			
		Total Porel (Kg)	0.00	0.00	0.00	0.00	0.00	0.00	45.10	45.10	45.10	45.10	45.10	45.10	45.10	40.59	36.53	32.88	29.59	29.59	
		Porec (Kg)														45.10	40.59	36.53	32.88	29.59	
	ACOF (m ²)	125.00	125.00	47.19	47.19	47.19	47.19	17.12	17.12	17.12	17.12	17.12	17.12	17.12	94.93	94.93	94.93	94.93	94.93		

Note: Porel=Planned Order Release; Porec=Planned Order Receipt;

From data in Table 1. and Table 2., we can simulate our algorithm. The result showed by Table 3. and Table 4. Table 3. illustrates the seeding scheduling of PSC 1. Table 4. illustrates the planting scheduling of PSC 1 Farmer 1. All GH and OF used efficiently. All orders are fulfilled on time and right product. There is not back order and lost sale. So, we can minimize the production cost.

5. Conclusion

The PSC has an important role in production and controlling of each farmer. By conducting a central seeding, farmers are only responsible and focused on planting vegetables. And the company is only focused for seeding, packing and distribute the vegetables. Determining the right amount of planting and planting schedule can control the harvest schedule and the right amount of harvest. We can reduce maintenance cost, rent cost, and lost sales. So, we can produce with minimal production costs.

For further research we want to consider the soil treatment process and the variety of vegetables. Soil treatment is needed to maintain the quality of vegetables.

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