Current pattern of sugarcane harvesting in Thailand and its implication on the utilization of combine harvester

Puttipong Hongthong[1] and Aran Patanothai[1*]

ABSTRACT: The change from manual to combine harvesting of sugarcane will demand great changes in the harvesting pattern. An understanding of the current practices and lesson learned from an area where combine harvesters have long been used would be valuable for the planning of these changes. This research investigated the current sequential pattern of sugarcane harvesting in a selected village in Northeast Thailand and examined the implementation of combine harvesting in Palm Beach County in Florida. For the site in Thailand, a total survey with questionnaires was used to collect data on sequential harvesting for the individual fields in the 2012/2013 milling season. For the US site, data were obtained for the 2015/2016 milling season by interviewing a key informant coupled with field observations. The results showed that, in Thailand, the fields harvested in each of the sequential harvesting periods were scattered all over the village, so were the fields in each of the consecutive crop starting periods. No relationship was observed between crop starting dates and harvesting dates, resulting in great variations in crop age at harvest. Combine harvesting of sugarcane in Florida involved uniform planting in each field, estimating yields for the individual fields based on monthly data, allocating quota to individual farmers, making harvesting plan and discussing the harvesting schedule with farmers. Harvesting was done by caravans of harvesters, tractor wagons and trailers, which were controlled by the mill. Clearly, the current planting and harvesting practices for sugarcane in Thailand do not fit with machine harvesting and drastic changes are needed throughout the supply chain system. Framework, optimization models and supporting tools are available for designing plans for the supply chain components. However, close and continuous communication and participation among the parties involved are essential to building up trust and commitment in implementing the plans.

Keywords: sugarcane production, sugarcane harvesting, mechanized harvesting, sugarcane supply chain, supply chain management

Introduction

Thailand is one of the leading countries in sugarcane production and sugar exporter of the world. Production area of the crop in the country is around 1.6 million ha annually, producing about 104 million tons of sugarcane and about 11 million tons of sugar (OAE, 2016). Despite the vast production area, the crop is still harvested almost entirely by hand, which demands a lot of labor. Out-migration to the rapidly growing industry and service sectors has resulted in a continuous decline of agricultural labors (NSO, 2016). As a consequence, labors for sugarcane harvesting has become more and more scared. This has resulted in the untimely harvesting of the crop which affected sugarcane yield and quality and also the regularity of the cane supply to the sugar mill. To solve this problem, combine harvesters had been introduced and used by some large farmers. Sugar mills have also started to provide combine harvesters to help farmers in their service areas.

For combine harvesting to be efficient, however, an appropriate pattern of harvesting needs to be devised. The fields to be harvested in sequential order should be in the same direction to save time and cost of moving the

[1] System Approaches in Agriculture Program, Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand.

* Corresponding author: aran@kku.ac.th

harvester (Singh and Pathak, 1994; Arjona et al., 2001; Higgins and Davies, 2005). Appropriate age and type of sugarcane also need to be taken into account in designing the harvesting plan (Arjona et al., 2001; Higgins et al., 2004). An understanding of the current practices, particularly the pattern of harvesting, is a prime prerequisite to seeing what changes are needed. Lesson learned from the area where combine harvesters have long been used would also be useful for guiding the design of those changes.

The objectives of this research were to investigate the current sequential pattern of sugarcane harvesting in a selected village in the production area of the Mitr Phu Wiang sugar mill in Northeast Thailand, and to examine the process of sugarcane harvesting by combine harvesters in Palm Beach County near Belle Grade City in Florida in the United States. The results will help the mill in the formulation of measures to be implemented for a smooth transfer from labor harvesting to combine harvesting in its service area. These can be a model for other mills in Thailand and also in the neighboring countries when labors become scared.

Materials and methods

In Thailand, a village was taken as a study unit for investigating the sugarcane harvesting pattern, following the strategy of "one village one harvester" of the sugar company Mitr Phol Group. Hin Kong village in Ban Fang district of Khon Kaen province in Northeast Thailand, a village under the sugarcane productivity increasing program of the Mitr Phu Wiang sugar mill, was chosen as the study site. This village is located about 45 km southwest of Khon Kaen city (16° 21' 41.20" N, 102° 32' 39.72" E, 212 m above sea level). Its area resembles the dominant sugarcane production area with sandy soil in undulating terrains in Northeast Thailand. Palm Beach County near Belle Grade City in Florida (26° 41' 7" N, 80° 40' 17" W, 6 m above sea level) was selected as the site where combine harvesting of sugarcane has long been used. Sugarcane production in this area is under the management of the Sugar Cane Growers Cooperative of Florida.

At Hin Kong village in Thailand, data were collected during the 2012/2013 milling season from November 2012 to April 2013. There were 108 households that grew sugarcane in 113 fields. Field sizes of the crop ranged from 0.16 to 1.8 ha, with the average being about 1.13 ha. The distance of the supporting area was 50 km around the mill. A total survey with a questionnaire was used to obtain data for all the 113 fields. Farmers were interviewed on field location, crop class, crop starting date (planting date for the plant crop or harvesting date of the previous crop for the ratoon crop), harvesting date, the decision making in harvesting the crop, and crop yield for each field. Information on the quota allocation and distribution were also obtained from the interview. Maps of these fields were obtained from the Mitr Phu Wiang sugar mill. Data on CCS of the individual fields could not be obtained, since the canes from different fields were mixed at the transfer station before being transported to the mill.

For the site at Belle Grade in Florida, information was collected on the quota allocation and distribution, and the sugarcane harvesting and transporting system by interviewing the Vice

President of the Agriculture Division of the Sugar Cane Growers Cooperative of Florida. Actual observations were also made on the harvesting and transportation of sugarcane from the fields to the mill during the 2015/2016 milling season.

Data collected from the Hin Kong village in Thailand were analyzed by making sequential mappings of the fields that were harvested or started at consecutive two-week periods from which the harvesting pattern or the starting pattern was determined. Ages of sugarcane at harvest for the individual fields were also calculated. Information for the US site was used in describing the management system for combine harvesting and transportation of the canes to the mill throughout the milling season. These were used as a basis for suggesting the changes in practices for an effective use of combine harvesting at the site in Thailand.

Results

Harvesting and planting patterns of sugarcane in Hin Kong Village in Northeast Thailand

In the 2012/2013 growing season, there were 113 sugarcane fields in Hin Kong Village. Forty-eight fields (42.5 %) were plant crop and 65 (57.5 %) were ratoon crop. Sugarcane was planted in the late rainy season (October to November) without irrigation. Fields of both crop classes were scattered throughout the village area with no observable striping pattern. Sugarcane harvesting began in early December 2012 and finished in late-March 2013. The data on the numbers of fields harvested in the consecutive two-weeks periods showed an unequal distribution, being more during the mid-milling season than during the early- or late-milling season. In any period, both the plant-crop fields and the ratoon-crop fields were harvested in more or less the same proportion with no clear sequential pattern of harvesting for the different crop classes (data not shown).

Figure 1 shows the geographical distribution of the sugarcane fields in Hin Kong Village that were sequentially harvested in the consecutive two-weeks periods during the harvesting season. It was quite apparent that the fields harvested in each period were scattered all over the village area with no clear striping pattern of sequential harvesting. The fields that had the starting time of the crop (time of planting or time of the previous harvesting) in the individual two-week periods also showed a scattered distribution (data not shown). These planting and harvesting patterns certainly would not fit the effective operation of combine harvesting of sugarcane.

The dominant effect of the current sequential planting and harvesting patterns was the great variations in the age at harvest of the crop in the individual fields, ranging from 7 to 17 months (**Figure 2**). This was the result of a longer period of the starting times (six months) than the harvesting period (four months). The durations of the plant crop were always longer than those of the ratoon crop. In additions, the daily variations in crop duration were largely from the daily variations in the duration of the ratoon crop.

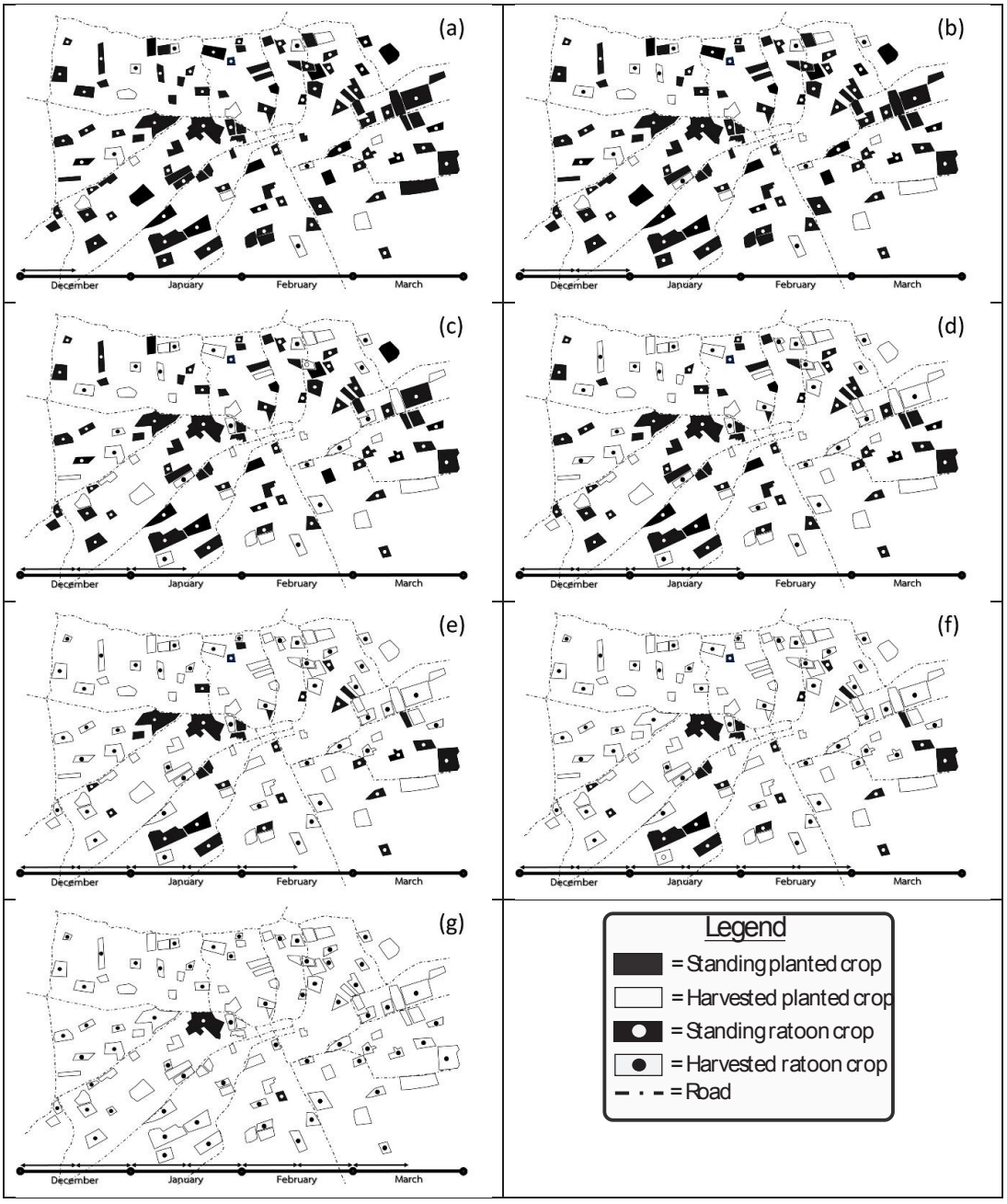


Figure 1 Fields of the plant crop and the ratoon crop of sugarcane at Hin Kong village that were harvested during mid-December 2012 (a), the end of December 2012 (b), mid-January 2013 (c), the end of January 2013 (d), mid-February 2013 (e), the end of February 2013 (f) and mid-March 2013 (g).

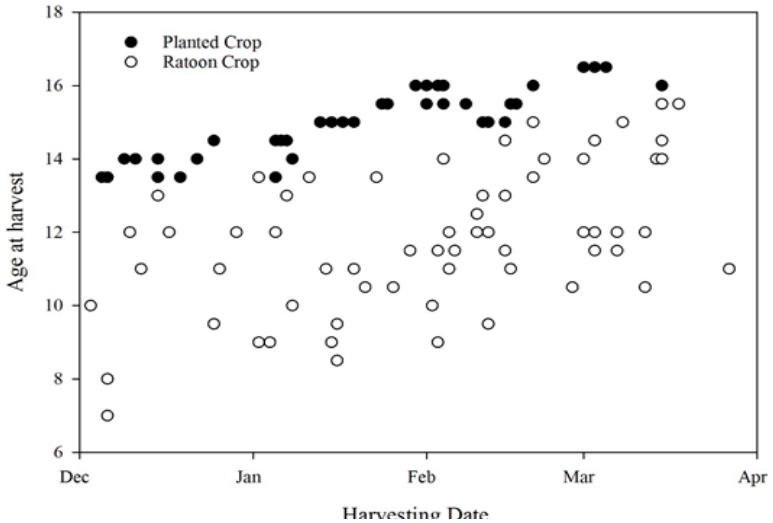


Figure 2 Variations in the age at harvest (crop duration) of the plant crop and the ratoon crop in different fields in Hin Kong Village in the 2012/2013 milling season.

In this study, no relationship between crop yield with crop starting date, crop harvesting date, and crop duration was observed (correlation coefficients ranging from -0.27 to 0.19, $p > 0.05$). Several fields, however, were harvested when crop ages were less than 10 months or more than 13 months. These ages at harvest have been found to reduce the CCS value of the crop (Hongthong, 2016), thus, the current planting and harvesting patterns should have a negative effect on the CCS value of the crop in those fields.

Harvesting of any sugarcane field depended very much on the quota to deliver the harvested canes to the mill and the availability of labors. During the milling season, the sugar mill allocated quota to quota contractors, in rounds, periodically. Quota contractors, in turn, allocated the quota they received in each round to farmers who are members of their groups. These quota contractors, in general, are large farmers who also have their own sugarcane fields. They also have group members from other nearby villages as well. Some farmers sold their sugarcane before harvesting (pre-harvest selling), mostly to the quota contractors of their respective groups. Thus, the quota contractors played a key role in the decision to harvest sugarcane fields.

Planting and harvesting system of sugarcane in Palm Beach County in Florida

The US is also an important sugarcane producing country of the world, and Florida is the top sugarcane producing state (The Statistics Portal, 2016). Palm Beach County accounted for more than 75 % of the total sugarcane acreage in Florida (Baucum and Rice, 2009). Most sugarcane planted areas are around Lake Okeechobee in Belle Glade City where the Sugar Cane Growers Cooperative of Florida was located. The Cooperative is a vertically integrated agricultural enterprise that was set up to harvest, transport and process sugarcane grown by its

member farms in an area of about 28,000 ha (Sugar Cane Growers Cooperative of Florida, 2016). The Cooperative also owns a sugar mill that has the grinding capacity of 26,000 tons of sugarcane day^{-1} or three million t year^{-1}.

In the 2014/2015 milling season, there were 47 small to medium size farms under contract with the Cooperative. Field sizes of the crop ranged from 4 to 600 ha, with the average being about 200 ha. The distance of the supporting area was 60 km around the mill. Mechanization was used throughout the production system, from land preparation to harvesting and hauling sugarcane to the mill. Ninety percent of the area were planted during October to November, while the rest were planted in January to February. Planting was done by machine with the furrows spaced 1.5 m apart which is suitable for the operation of the combine harvester. In this area, 5-6 cultivars were grown, but only one cultivar was planted in each field. The mill had all the information on the time of planting, cultivar planted, crop managements and age of the crop at a specific date for each field.

Sugarcane harvesting in Florida started in late October and ended in mid-April. Before the start of the milling season, the mill conducted a yield estimation for each field, based on monthly information sent by the owner. The mill, then, allocated the monthly cutting quota (in percent of weight) to each large member farm throughout the milling period, as shown in **Table 1** for examples. Farmers who have small areas were allowed to choose the delivering time within the suitable range of crop duration, but with the consent of the mill.

Table 1 Examples of monthly cutting quota allocation to individual large farms.

Category	Monthly quota allocation							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Percent allocated	10	15	20	20	15	10	10	100
Farmer A (tons)	1,200	1,800	2,400	2,400	1,800	1,200	1,200	12,000
Farmer B (tons)	6,400	9,600	12,800	12,800	9,600	6,400	6,400	64,000

After quota allocation, farmers and the mill met to determine the sequence of harvesting for the individual fields by day and month. The factors considered include crop class (plant crop or ratoon crop), land use (whether other crops were planted before planting sugarcane which would affect the planting date), location (distance from the caravan of harvesters) and cultivar (appropriate age at harvest for the cultivar grown). Acceptable ages at harvest were 13-15 months for the plant crop and 9-12 months for the ratoon crop. A clear harvesting plan by day and month was then developed taking into account all these factors to achieve the appropriate age of sugarcane, the minimum harvesting cost, and the daily crushing capacity of the mill.

Harvesting was done by combine harvesters operated by the mill. In the 2015 milling season, there were 38 combine harvesters and accompanying wagons and trailers to transport the harvested canes. The harvesters were organized into caravans, each consisted of four

harvesters, four tractor wagons and six to eight trailers. The harvesters in a caravan operated in tandem, followed by strings of tractors and wagons to put the canes that came out of the harvesters. The canes were then loaded onto the trailers for transporting to the mill. Harvesting was done on both green sugarcane and burned sugarcane. Green sugarcane could be harvested anytime, but the burning of sugarcane in each field had to receive a permit from the state government office one day in advance. Burning was done in the afternoon and the crop was harvested in the morning of the next day. Pre-harvest burning of sugarcane was a preferred practice because the leaves were removed, facilitating the operations of combine harvesting, transportation and processing of sugarcane.

Thus, the sugarcane harvesting system in Florida directly involved the uniformity of planting system in each field that included a single cultivar and the same time of planting. Data for each field made it possible to accurately predict yield, which was used to determine the suitable range of cutting dates. Quota allocation to fit the daily capacity of the mill and an agreed plan of sequential harvesting were the main mechanism for achieving the efficiency of harvesting operation and the appropriate age of the crop at harvest. The use of a caravan of combine harvesters, wagons and trailers as an operating unit provided a flexible but efficient cutting and transporting process that could be controlled directly by the mill. The system worked well with large-size fields. However, the necessary conditions for the success of this process appeared to be a strong farmer organization and an efficient management system.

Discussions

This study was intended to determine the sequential pattern of harvesting of sugarcane in the service area of a sugar mill in Northeast Thailand, taking a village as a study unit. It was thought that if the current harvesting practices showed some signs of a sequential striping pattern, changing from manual harvesting to combine harvesting should not be much difficult. The results, however, showed that the fields that were harvested in the sequential periods throughout the milling season were scattered all over the village area with no sign of the sequential striping pattern. The same was also shown for the sequential starting times of the crop in the different fields. Clearly, the current practices in planting and harvesting of sugarcane in Thailand do not fit with combine harvesting. The investigation on the operation of combine harvesting of sugarcane in Florida was intended to provide lessons learned that could be applied to the Thai conditions. The results clearly indicated the need for drastic changes in practices throughout the supply chain system, if combine harvesting is to be used effectively and efficiently. As sugarcane fields in Thailand are small and are owned by a large number of farmers, for combine harvesting to be efficient, it would also be necessary to combined fields in the service area into individual harvesting units, each consists of a group of adjacent fields.

The supply chain of sugarcane is complex, involving growing, harvesting, transporting and processing sugarcane from the field to the mill. The use of combine harvester demands a synchronization of these processes. This requires the design of an overall integrated plan that

includes plans of the individual components. The modeling framework that captures the key linkages and drivers as proposed by Higgins et al. (2004) could be used as a basis for designing such a plan. The decision support system developed in the early years for mechanical harvesting and transportation of sugarcane in Thailand (Singh and Pathak, 1994) could also be used as a starting point for modification with new models and tools.

Bocca et al. (2015) highlighted three key component plans in the supply chain system. These included the crop plan that optimizes the delivery of raw material to the mill with the highest quantity of mill capacity, the harvest plan that determines which plots will be harvested at a given time, and the harvest schedule that specifies the sequence of harvesting the individual fields, taking into account the logistics of moving between various harvesting areas. There are optimization models that could be applied to sugarcane, including models to support the crop plan (Grunow et al., 2007; Piewthongngam et al., 2009), the harvesting plan and the harvesting schedule (Grunow et al., 2007; Jena and Peggi, 2013).

Lessons learned from Florida indicated that the estimation of yields of the individual fields was a key process that provided the basis for quota allocation. Bocca et al. (2015) pointed out that yield predictions could be included in the optimization model to support the crop plan, the harvesting plan and harvesting schedule. Several methods are available for yield prediction, including crop simulation models, such as APSIM-Sugarcane (Keating et al., 2003) and DSSAT/Canegro (Jones et al., 2003), empirical model (Meinke and Stone, 2005), and even prediction by specialists. Their applications depend on the availability of the required data. Monthly data of the individual fields also allowed the mill to design the harvest plan and determine the harvest schedule. Data collection and management are, thus, an essential element that needs to be developed. For the case of the Mitr Phu Wiang sugar mill in Thailand, the database of sugarcane in individual farmers' fields has been planned, and maps of all the fields are available. Now that every farmer already has a mobile phone, it should be possible to have them send in monthly data for each field like what has been done in Florida.

The most difficult part is the implementation of the plan which needs to be mutually agreed by all parties involved. In Palm Beach, Florida, there are not many sugarcane growers in the service area of the mill which is owned by their Cooperative. The Cooperative is also strong and has an efficient management system. Decision-making, for the large part, is centralized with the Cooperative management, making it easy to implement the plan. The conditions in Thailand are quite different. There are a large number of sugarcane growers in the service area of the mill and most of them own small-size fields. Farmers, quota contractors and farmers are all involved in the supply chain management. Decision-makings are done at different levels and by different parties. With a large number of people involved, to get agreement and commitment from all parties is a formidable task but necessary. Encouraging adoption of the radical change in a complex sugarcane supply chain system requires increased participation and learning between the growing, harvesting and milling sectors. Supports

by outside help in systems development and change management are also needed (Pannell, 1999; Higgins et al., 2004).

Supply chain management requires collaboration among partners. The main attributes of collaboration are stability, reliability, trust, personal relationship and communication (Bezuidenhout et al., 2012a). A willingness to share risks in order to achieve the mutually-agreed long-term goal is also needed (Sahay and Maini, 2002). Building a good collaborative relationship is the task that the mill has to take to be able to effectively manage its sugarcane supply chain. It will be some more years before combine harvesters can be put into operation in large scale. Meanwhile, the mill should start working with quota contractors and farmers in combining fields, changing the planting pattern, allocating delivery quota and setting the harvesting schedule just like what would be done with combine harvesting, but still use labors in harvesting which are managed by the mill. This would enforce close communication and participation among the involved parties, learning together, building trust and commitment, preparing for actual implementation of combine harvesters when the time comes.

Conclusions

The results of this study indicated that the current sequential patterns of planting and harvesting of sugarcane in Thailand do not fit with machine harvesting with combine harvesters. Lessons learned from supply chain management of sugarcane in Florida pointed out the need to make drastic changes in all steps along the sugarcane supply chain from planting to transporting sugarcane to the mill if combine harvesters are to be used. With a large number of farmers who operate small sugarcane fields, these radical changes would be very difficult but unavoidable. Integrated plans for the different stages of the sugarcane supply chain need to be developed to guide the implementation. Framework, optimization models and supporting tools are available for designing these plans with outside help in systems development. The crucial part is to get the agreement and commitment of all parties in implementing the plan. Close and continuous communication and participation among involved parties are essential to building up trust and commitment. The mill should take the initiative and be the lead in making these changes a reality.

References

Arjona, E., G. Bueno, and L. Salazar. 2001. An activity simulation model for the analysis of the harvesting and transportation systems of a sugarcane plantation. Comput. Electron. Agric. 32: 247-264.

Baucum L. E., and R.W. Rice. 2009. An overview of Florida sugarcane. Publication SS-AGR-232. Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Bezuidenhout, C.N., S. Bodhanya, and L. Brenchly. 2012a. An analysis of collaboration in a sugarcane production and processing supply chain. British Food J. 114(6): 880-895.

Bezuidenhout, C.N., S. Bodhanya, T. Sanjika, M.S. Sibomana, and G.L.N. Boote. 2012b. Network analyses approaches to deal with causal complexity in a supply network. Int. J. Prod. Res. 50(7): 1840-1849.

Bocca, F.F., L.H.A. Rodrigues, and N.A.M. Arraes. 2015. When do I want to know and why? Different demands on sugarcane yield predictions. Agric. Syst. 135: 48-56.

Grunow, M., H.O. Gunther, and R. Westinner. 2007. Supply optimization for the production of raw sugar. Int. J. Prod. Econ. 110: 224-239.

Higgins, A., G. Antony, G. Sandell, I. Davies, D. Prestwidge, and B. Andrew. 2004. A framework for integrating a complex harvesting and transport system for sugar production. Agric. Syst. 82: 99-115.

Higgins, A., and I. Davies. 2005. A simulation model for capacity planning in sugarcane transport. Comput. Electron. Agric. 47: 85-102.

Hongthong, P. 2016. Variations in yield and quality of sugarcane in a specific area and their causal factors. Ph.D. Thesis. Khon Kaen University, Khon Kaen.

Jena, S.D., and M. Poggi. 2013. Harvest planning in the Brazilian sugar cane industry via mixed-integer programming. Eur. J. Oper. Res. 230: 374-384.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003. The DSSAT Cropping System Model. Eur. J. Agron. 18: 235-265.

Keating, B.A., P.S. Carberry, G.L. Hammer, M.E. Probert, M.J. Robertson, D. Holzworth, N.I. Huth, J.N.G. Hargreaves, H. Meinke, Z. Hochman, G. McLean, K. Verburg, V. Snow, J.P. Dimes, M. Silburn, E. Wang, S. Brown, K.L. Bristow, S. Asseng, S. Chapman, R.L. McCown, D.M. Freebairn, and C.J. Smith. 2003. An overview of APSIM, a model designed for farming systems simulation. Eur. J. Agron. 18: 267-288.

Meinke, H., and R.C. Stone. 2005. Seasonal and Inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations. Clim. Change. 70: 221-135.

NSO (National Statistical Office). 2016. Directions of work and employment of Thai labors. National Statistical Office. Available: https://goo.gl/xAtdZk. (in Thai). Accessed May 10, 2016.

OAE (Office of Agricultural Economics). 2016. Agricultural Statistics of Thailand 2015. Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Pannell, D.J. 1999. Social and economic challenges in the development of complex farming systems. Agroforest. Syst. 45: 393-409.

Piewthongngam, K., S. Pathumnakul, and K. Setthanan. 2009. Application of crop growth simulation and mathematical modelling to supply chain management in the Thai sugar industry. Agric. Syst. 102: 58-66.

Sahay, B.S., and A. Maini. 2002. Supply chain: a shift from transactional to collaborative partnership. Decision 29(2): 67-88.

Singh, G., and D.K. Pathak. 1994. A decision support system for mechanical harvesting and transportation of sugarcane in Thailand. Comput. Electron. Agric. 11: 173-182.

Sugar Cane Growers Cooperative of Florida. 2016. Who we are. Available: https://goo.gl/K2ge4Q. Access May 8, 2016.

The Statistics Portal. 2016. Sugar cane production in the U.S. from 2010 to 2015, by state. Available: https://goo.gl/JrKGf6. Accessed May 5, 2016.