Simulation Modeling of Raising Meat Goat Farming System: Case Study of Farms in Satun, Thailand

Thitinan Sorabut
Faculty of Natural Resources, Prince of Songkla University, Thailand
E-mail: thiti_tk249@hotmail.com

Vichot Jongrungrot
Faculty of Natural Resources, Prince of Songkla University, Thailand
E-mail: vichot.j@psu.ac.th

Pin Chanjula
Faculty of Natural Resources, Prince of Songkla University, Thailand
E-mail: pin.c@psu.ac.th

Abstract
Goat raising in Thailand is not different in practices from other types of agriculture in terms of its small-scale household owned and diversity of activities. This study was conducted on 5 farmers practiced different 5 systems in Satun province, Thailand. Many farmers have built economic resilience in the agricultural farming systems under risks and uncertainties brought by changing government policies. This study seeks to examine the resilience of the economy through the scenario building in an integrated goat-other agricultural activities farming system adapted by farmers when facing external threats. This study found that the total annual margin of raising goats, with large diversity from 2.27 to 30.51 percent and in terms of cost and benefits of 5 plots in 2018 showed a gross margin of between 49,002 to 306,313 baht per year and plot 2 was an interesting farming system with higher net profits than the other plots. Since, the goat has low operation cost, it plays an important role as source of income to compensate for the lower margin when the economic crop price is low and in times when goat price is also low, farmers adjust management to reduce costs to offset lower margins. This research revealed values of economic resilience in the goat farming system which could be important to an integrated goat with other agricultural activities development.
Keywords: Simulation Modeling, Farming System, Meat Goat, Raising

Introduction
In Thailand, goat raising seems to increase continuously every year, especially in the Southern Border Provinces. That is because approximately 80 percent of the population in these areas are Muslims, and they have a demand for goat in religious ceremonies and traditions. Basically, household practicing goat raising will be alongside with other agricultural activities, such as para rubber tree, oil palm plantation, fruit trees, etc. (Suthummanon, et al., 2011) In Satun goat undeniably plays a vital role. Throughout the province, goats are a good, stable source of livelihood especially for the poor in the rural areas. Goat production is mostly carried out by smallholders where the animals are kept in small flocks at an average of 5-10 head/family. The goat has been raised in Satun for their meat and milk and is still gradually increasing. Satun province has a total area of 1,754,701 Rai (1 Rai = 1,600 square meters.) which provided 635,847 Rai or 36.24 percent of the total area for agricultural activities, especially rubber plantations, oil palm plantations, rice fields,

and orchards (Satun Provincial Administrative Organization, 2018) . However, there are 19,949 farmers raising animals, goats raising is 25 percent of the total animal raising farmers. (Satun Provincial Livestock Office, 2018) . Thai government has policy and strategy, to support Satun province as the biggest goats market in the south through constructing domestic and international slaughterhouses and increasing goats raising in the province. Most of the farmers often must confront the raising, farming, and marketing problems which may cause them to stop their goat raising. On the other hand, there are still some farmers who continue raising the goats and do other agricultural activities.

Background and simulation for livestock farming system

The goat population in Thailand is relatively small. However, owing to heightened demand for goat products such as meat and milk, the population of goat increased in the recent years and that sparked interest of researchers to study goat more especially dairy goats. The knowledge together with the government's efforts to promote goat production has resulted in the steady increase in the goat population (Pralomkarn, et al., 2012). In a pursuit to establish an in-depth understanding of the goat farming system, an agro-economic simulation model was developed to facilitate a comparison of the impact of management, market, and biological factors on the cost of providing ruminant livestock with feed grown on the farm (home-produced feed) Finneran, et al.,(2010). For livestock farmers, one of the most important groups of management decisions is that relating to feeding provision. According to Finneran, et al., (2012), feed constitutes the greatest cost in the inputs in any animal production system. Since feed cost constitutes such a large proportion of the total cost, it is imperative that feeding must be managed strategically for economic sustainability and profitability of livestock farms). Furthermore, Gettins, et al., (2020) suggest that simulation models have the potential to capture a large number of operational details and support the decision-making process; however, livestock simulation models research is still very limited. In this paper, Olympe software was used to model and simulate the meat goat farming system and integrated meat goat-other farming system to compare the different farms on the basis of their economic features as well as the total household income.

Model Description

Olympe is a decision support software which can be used to investigate management strategies used by farmers to improve farmer's or groups of farmers' understanding of their own situation and their socio-economic context. It can be used as a data base, economic calculator and also as a simulation tool that allows prospective analysis based on either hazardous situations that farms face such as price fluctuations and adverse weather conditions or the consequences of new investment, the removal or addition of a productive farming system, change in a cultural practice calendar, technical change, and integrate the risks through evaluation of consequences of possible events (Attonaty, et al., 2010).

Research Objectives

The objectives of this research are (1) to investigate mixed goat- other agricultural activities management, (2) to evaluate the performance of economic margin and (3) to assess the economics of integrated goat-other agricultural activities farming systems perturbed by external hazards in Satun province of southern Thailand.

Research Methodology

Data collection

1) This study used purposive sampling for selecting five farmers practicing integrated goat-other agricultural activities farming systems in Satun province Thailand as study sample farms.

2) The primary data was collected by using questionnaires to interview integrated goat-other agricultural activities farming systems farmers in 2018. The changing products and inputs in farms from 2018 to 2027 were based on farmers planning such as the number of dried rubber

products by age of rubber trees (Table 1). Moreover, related prices of all products and inputs from 2019 to 2024 were fixed in 2018.

Table 1. Amount of dried rubber products

Age of rubber trees (year)	Amount of dried rubber products (Kg/hectare/year)	Amount (%)
7-9	1,531	64
10-12	2,375	100
13-15	1,900	80
16-18	1,575	66
Over 19	1,350	57

Source: Calculation based on Chhiev and Jongrongrot (2021)

Data analysis

1) To understand cost and benefit (profit, net income, and gross margin) of different five integrated goat-other agricultural activities farming systems farms in 2018, Olympe software was used to simulate.

2) To understand the economic margins of different plots for a 10-year period (2018 to 2027), Olympe software was used to simulate.

3) Scenario building concerning price hazard was created concerning price hazard: the price of meat goat from 2021 to 2027 reduces 20 % from fixed meat goat price, based on the price of meat goat in 2018 at the local market in Satun.

4) Scenario building concerning risk reduction to increase yield upon worth for the investment at the appropriate time.

Research Results

Costs analysis of the farming system

Figure 1 shows the cost and preparation of five plots in 2018 were as follows:

1) Plot 2 the farming system raising 30 goats with rubber trees and oil palm farm within the area of 22 rai incur the highest costs (130,914 baht/year) because there are high fixed cost of the goats' house depreciation and high variable cost of the oil palm farm such as the chemical fertilizer, the labor expense for harvesting, and selling oil palm products.

2) Plot 4 the farming system raising 57 goats with rubber trees and rice within the area of 5 rai incur the second-highest costs (84,654 baht/year) but the highest variable costs from goats raising. The variable costs of rubber tree cultivation and rice farming are low as they are produced in a smaller area compared to plot 5

3) Plot 6 the farming system raising 18 goats with rubber trees and sweet-corn within the area of 13 rai incur the third-highest costs (77,645 baht/year). Most of the variable costs are for sweet corn cultivation and raising goats. Although the farming system has the lowest number of the raised goats, the expense is high as the farmers need to pay for the condense food and the oil for the chopping machine of the palm tree and sweet corn which are used to mix with the condense food to feed the goat regularly instead of the grasses.

4) Plot 5 the farming system raising 19 goats with rubber trees, oil palm and rice within the area of 28.5 rai incur the fourth highest costs (75,378 baht/year) which are almost similar to plot 6 above. Most of the variable costs are incurred with oil palm farming and rubber tree farming in almost the same amount of proportion and rice farming, respectively. Even though, this farming system is the second-lowest of goats raising, the variable cost of raising goats is high, due to the condense food added to feed the goats in the evening, all-day feed for processed mineral and the artificial insemination expense.

5) Plot 1 the farming system raising 30 goats with rubber trees within the area 10 rai uses the lowest costs (24,100 baht/year) as the cultivation area is the third lowest rank. Although the

farming system is the third lowest of the raised goat number, the usage of the variable cost is the second-lowest rank. As the goats are freed to graze in the rubber plantation. Additionally, there is no condense food mixed, and some of the inputs such as the medical or processed mineral are supported by the Department of Livestock Development.
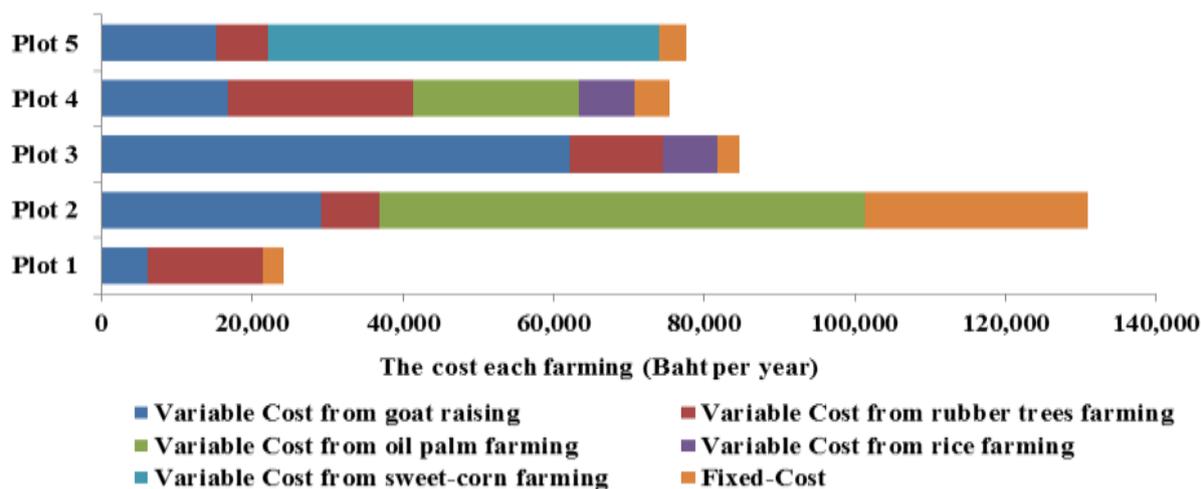

Figure 1 The variable and fixed costs of five plots in 2018

Benefit analysis of the farming system
In terms of benefits, Table 2 shows the comparison margin of the studied farming systems of the five plots in 2018, the original on-farm margin distribution between goats, rubber, oil palm, rice, and sweet-corn activities, and the various level of margin diversification. The result of these simulation gross margin of five plots found that plot 2 had the highest gross margin which is 306,313 baht per year in 2018. Most of the margin 63.32 percent derived from rubber followed by oil palm at 34.41 percent which the remaining 2.27 percent derived from raising goats. Because this plot had the largest rubber trees cultivation area and several activities with great management in farms such as the chemical fertilizer and manure were used alternatively, the soil was fertile, and rubber trees were rich in nutrients, causing the high amount of the products. Meanwhile, raising goats can provide consistently high yields. Plot 1 had the second-highest gross margins which are 256,346 baht per year and plot 3 had the lowest gross margin. The results of five plots revealed that the margin of raising goat ranged from 4,247 to 27,490 baht per year, with a very large diversity from 2.09 to 30.51 percent. Each farming system had different benefits because of some factors such as operation cost, the amount of production, the value of associate production, production management as well as marketing.

Table 2 On-farm margin origin per plot

Type	Goat		Rubber		Oil palm		Rice		Sweet-corn	
	Margin (Baht/Year)	% ∑M	Margin (Baht/Year)	% ∑M	Margin (Baht/Year)	% ∑M	Margin (Baht/Year)	% ∑M	Margin (Baht/Year)	% ∑M
Plot 1	27,490	10.72	228,856	89.28	0	0	0	0	0	0
Plot 2	6,948	2.27	193,949	63.32	105,416	34.41	0	0	0	0
Plot 3	14,951	30.51	26,231	53.53	0	0	7,820	15.96	0	0
Plot 4	4,247	2.09	60,084	29.63	25,233	12.44	113,193	55.83	0	0
Plot 5	10,825	6.95	112,910	72.50	0	0	0	0	32,010	20.55

The study of gross net profit Figure 2 shows the comparison of the studied farming systems of the five plots in 2018 found that plot 2 had the highest gross net profit which was 276,726 baht per year Because the farmer had the second-largest cultivation area and several activities with great management in the farm such as the chemical fertilizer and manure were used alternatively, the soil was fertile, and the rubber tree and oil palm were rich in nutrients,

causing the high amount of the products. Meanwhile, raising goats can provide consistently high yields. Followed plot 1 had the second-highest gross net profit which of 253,716 baht, most of the returns derived from the rubber tree cultivation in which the goat faces were often used freely to fertilize the rubber trees and the rubber trees gave the high amount of the latex. Although the income from raising meat goats was low during the study period, the goat expenses were also low as there was government support. Finally, plot 3 had the lowest gross net profit which was 46,117 baht in 2018. Because the farmer had the smallest cultivation areas, 5 rai, that the first rubber plot started to yield with low product and the second rubber plot had 13 years old up which caused the product reduced. The rubber price was low during the study period which caused the lower use of chemical fertilizer, so the soil was less fertile and insufficient nutrient. Additionally, the closed shed goat raising with the given condense foods led to the high expense and fuel for going to the rubber plots and goat farm increased the farm costs.
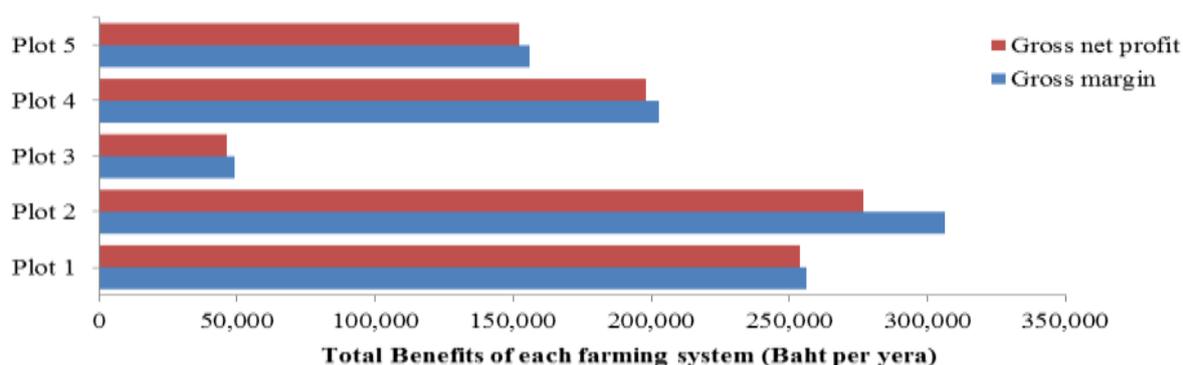

Figure 2 Comparison of total benefits of six plots in 2018.

The economic margin
Plot 1 the raising goat along with rubber trees farming system: There are 2 products in this plot, i.e. goat and rubber. Simulation for the 10-year period from 2018 to 2027 with the related price, fixed in 2018, indicates that (Figure 3), the farmer will get high goat margin from 2018 to 2022, 2023 goat margin decreased and increased again in 2024 because margin of raising goats fluctuate according to breeder cycle, and goat production quantity. Rubber income will decrease in sequence because the rubber products will decrease by age. In the last year of the simulation (2027), goat and rubber products will share a margin of about 188,481 and 145,066 baht per year, respectively. The gross margin from this plot in 2022 had a high gross margin which was 372,766 baht per year higher than that in 2018 for about 44.28 %, and the gross margin in 2027 equaled 333,547 baht per year higher than that in 2018 about 29.09% but lower than in 2022 about 11.75%. Therefore, raising goats on this plot can compensate for the product or yield decrease and prevailing low prices of rubbers due to getting additional income from the goat. Moreover, the plot still has goat manure to use in rubber farming.
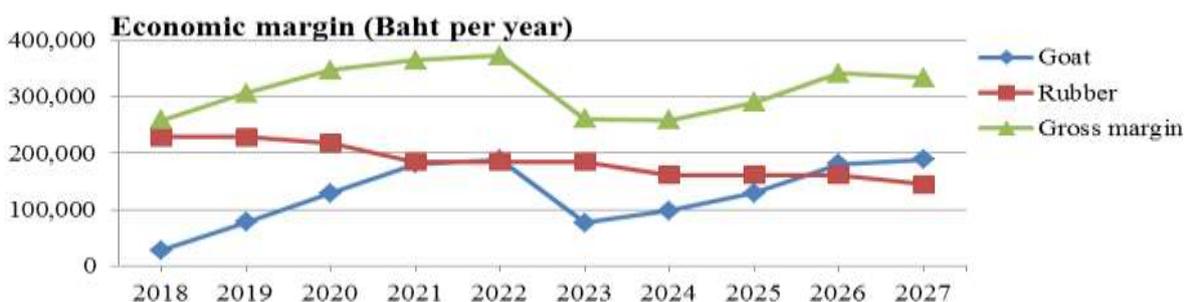

Figure 3 The economic margin of plot 1 from 2018 to 2027

Plot 2 the raising goat along with rubber trees and oil palm farming system: There are all 3 products in this plot, i.e. goat, rubber, and oil palm. Simulation for the 10-year period from 2018 to 2027 with the related price, fixed in 2018, indicates that (Figure 4), the farmer will get low and fluctuate goat margin every year because goat product has fluctuated according to breeder cycle, and goat production quantity, in 2023 to peak goat margin which was 154,894 baht per year. Meanwhile, the farmer will get a higher rubber margin to stay the same 3 years in 2020 to 2022 and will decrease in sequence because the rubber products will decrease by age. And the farmer will get lower oil palm margin in sequence because oil palm has been decreased by age. The gross margin from this plot in 2021 had a high gross margin which was 509,042 baht per year and in 2026 had a low gross margin which was 289,675 baht per year. In the last year of the simulation (2027) the product of goat, rubber, and oil palm leaves will share the margin 104,844, 199,724, and 74,123 baht per year, respectively. The gross margin from this plot in 2027 equaled 378,691 baht per year higher than one in 2018 for about 23.62 %. Therefore, plot 3 owner can overcome the low oil palm products and low rubber and oil palm price by introducing the mixed crops in the plot. Moreover, the plot still has wood products of rubber trees whose economic values will be accumulated by age, still has goat manure to use in rubber farming, oil palm farming, and the by-product of oil palm can be used for goat feed also.
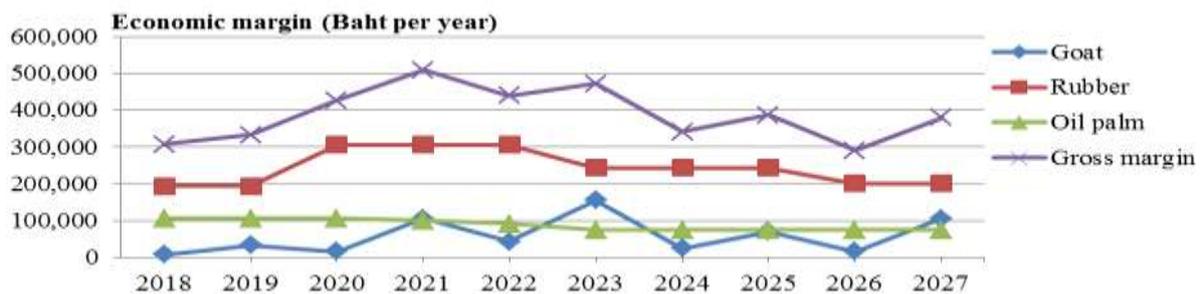

Figure 4 The economic margin of plot 2 from 2018 to 2027

Plot 3 the raising goat along with rubber trees and rice farming system: There are all 3 products in this plot, i.e. goat, rubber, and rice. Simulation for the 10-year period from 2018 to 2027 with the related price, fixed in 2018, indicates that (Figure 5), the farmer will get high goat margin from year by year to 2022 , 2023 goat margin decreased and increased again in 2026 because margin of raising goats fluctuate according to breeder cycle, and goat production quantity, the farmer will get lower rubber income in sequence because the rubber product has been decreased by age, And annual rice will get low and stable rice margin per year every year. The gross margin from this plot in 2022 had a high gross margin which was 119,786 baht per year and in 2018 had a low gross margin which was 49,002 baht per year. In the last year of the simulation (2027) the product of goat, rubber, and rice will share the margin of 170,324, 10,784, and 7,820 baht per year, respectively. The gross margin from this plot in 2027 equaled 188,928 baht per year higher than one in 2018. Therefore, in this plot, the farmer can overcome the low rubber products and low rubber prices by introducing the mixed crops in the plot. Moreover, the plot still has wood products of rubber trees whose economic values will be accumulated by age, still has goat manure to use in rubber farming, and rice farming and all trees can also be greatly used for environmental services.
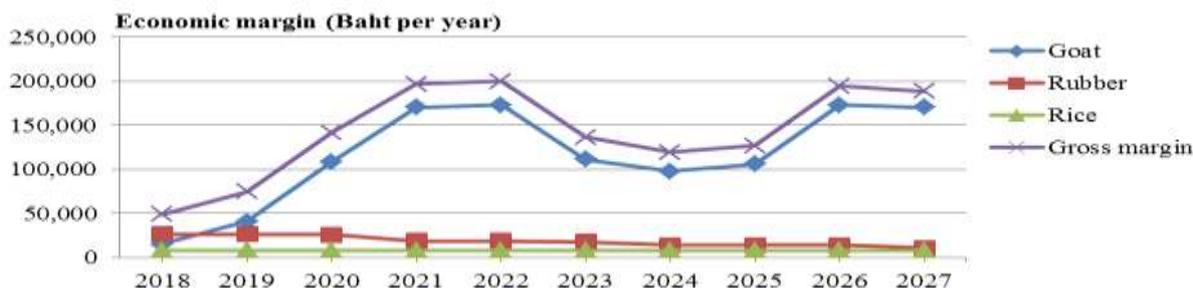
Figure 5 The economic margin of plot 3 from 2018 to 2027

Plot 4 the raising goat along with rubber trees, oil palm and rice farming system: There are all 4 products in this plot, i.e. goat, rubber, oil palm, and rice. Simulation for the 10-year period from 2018 to 2027 with the related price, fixed in 2018, indicates that (Figure 6), the farmer will get high goat margin from year by year to 2021 and to peak goat margin in 2023 because the margin of raising goats fluctuate according to breeder cycle, and goat production quantity. Meanwhile, the products of rubber to stay the same from 2018 to 2020 and will get low and stable rubber margin every year, and oil palm will lower margin to stay the same from 2018 to 2024, and stop yielding in 2024. And annual rice will get a high and stable rice margin per year every year, and a higher margin than rubber and oil palm. In the last year of the simulation (2027), goat, rubber, oil palm, and rice products will share the margin of about 61,121, 52,604, 0, and 113,191 baht per year, respectively. The gross margin from this plot equaled 226,918 baht per year higher than that in 2018 about 11.91 %. The gross margin from this plot in 2023 had a high gross margin which was 289,651 baht per year. Therefore, in this plot, the farmer can overcome the low rubber products, oil palm products, low rubber prices, and low oil palm prices by introducing the mixed crops in the plot. Moreover, the plot still has wood products of rubber trees whose economic values will be accumulated by age, still has goat manure to use in rubber farming, oil palm farming, rice farming and the by-product of oil palm can also be used for goat feed.
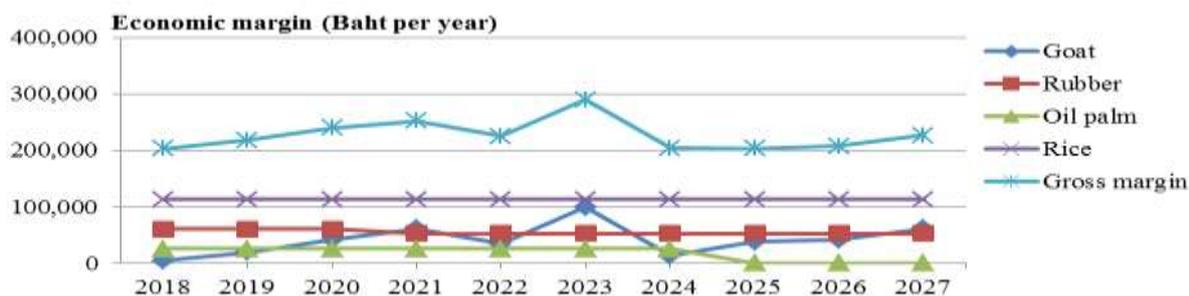

Figure 6 The economic margin of plot 4 from 2018 to 2027

Plot 5 the raising goat along with rubber trees and sweet-corn farming system: There are all 3 products in this plot, i.e. goat, rubber, and sweet-corn. Simulation for the 9-year period from 2019 to 2027 with the related price, fixed in 2018, indicates that (Figure 7), the farmer will get high goat margin from year by year to 2021 and to peak goat margin in 2023 because the margin of raising goats fluctuate according to breeder cycle, and goat production quantity. Meanwhile, rubber income will decrease in sequence because the rubber products will decrease by age. And annual sweet-corn will get a low and stable price margin per year every year, In the last year of the simulation (2027), goat, rubber, and sweet-corn products will share the margin of about 71,636, 61,188, and 32,010 baht per year, respectively. The gross margin from this plot equaled 164,834 baht per year higher than that in 2018 about 5.83 %. The gross margin from this plot in 2023 was high at 234,694 baht per year. Therefore, in this plot, the farmer can overcome the low rubber products and low rubber prices by introducing

the mixed crops in the plot. Moreover, the plot still has wood products of rubber trees whose economic values will be accumulated by age, still has goat manure to use in rubber farming and sweet-corn farming while the by-product of sweet-corn can be used for goat feed also.
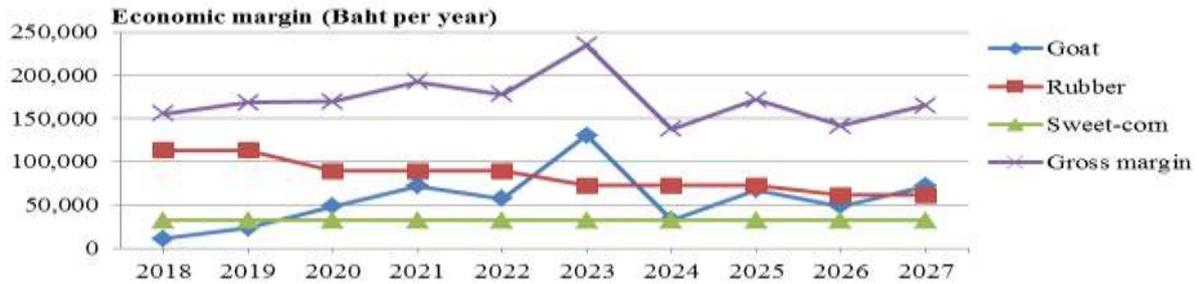

Figure 7 The economic margin of plot 5 from 2018 to 2027

Scenario building during 2021-2027
The changing in quantities of products and farm inputs from 2019 to 2027 was based on farmers' planning, and normal condition fixed meat goat prices in 2018, except those, appeared in the situation simulations.

Plot 1 the raising goat along with rubber trees farming system
1) First scenario (the goat price decrease): During 2021-2027 (7 years) plot margin of farm will decrease 208,146 Baht in total.
2) Second scenario (adjustment): The farmer decided to adjust raising breeding goats for up to 10 years to increase yield upon. During 2021-2027; the farmer earned a margin of farm 2,167,450 Baht in total or 306,684 Baht on average which can compensate for the lower margin of farm under first scenario (the goat price decrease). (Figure 8).
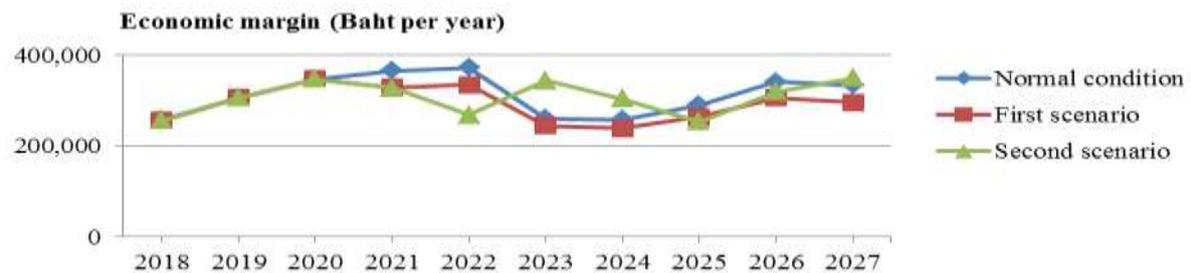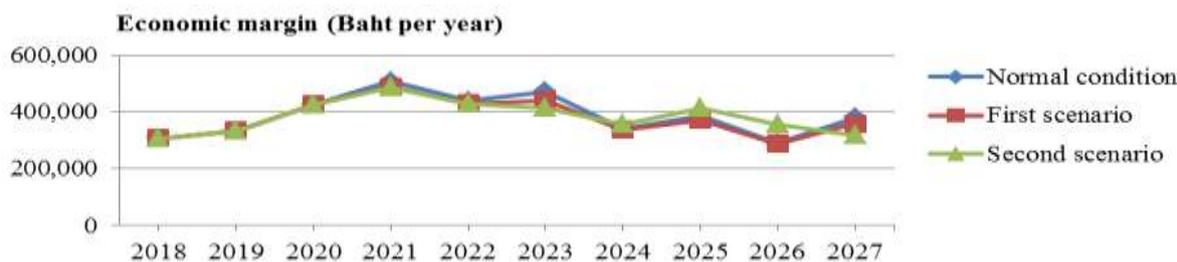

Figure 8 The economic margin of Plot 1 before and after simulation

Plot 2 the raising goat along with rubber trees and oil palm farming system
1) First scenario (the goat price decrease): During 2021-2027 (7 years) plot margin of farm will decrease 103,448 Baht in total.
2) Second scenario (adjustment): The farmer decided to adjust raising breeding goats for up to 10 years to increase yield upon, to reduce the feeding of goat concentrate and instead supplemented with fermented oil palm leaves and oil palm frond. During 2021-2027; the farmer earned a margin of farm 2,778,728 Baht in total or 381,838 Baht on average which can compensate for the lower margin of farm under first scenario (the goat price decrease). (Figure 9).

Figure 9 The economic margin of Plot 2 before and after simulation

Plot 3 the raising goat along with rubber trees and rice farming system
1) First scenario (the goat price decrease): During 2021-2027 (7 years) plot margin of farm will decrease 200,335 Baht in total.
2) Second scenario (adjustment): The farmer decided to adjust raising breeding goats for up to 10 years to increase yield upon and to reduce the feeding of goat concentrate. During 2021-2027; the farmer earned a margin of farm 1,098,104 Baht in total or 157,584 Baht on average which can compensate for the lower margin of farm under first scenario (the goat price decrease). (Figure 10).
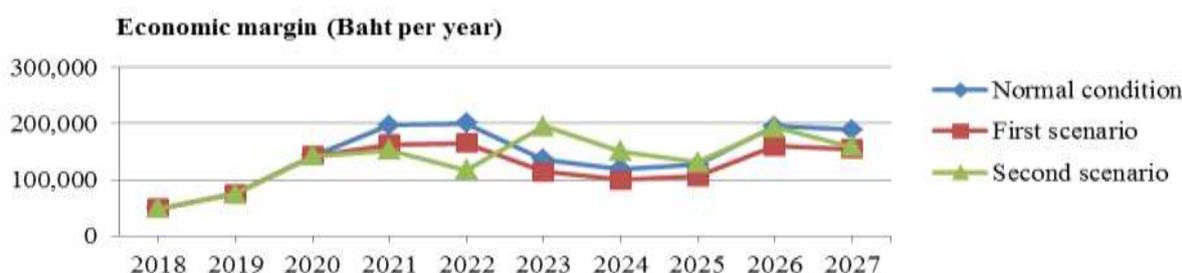

Figure 10 The economic margin of Plot 3 before and after simulation

Plot 4 the raising goat along with rubber trees, oil palm and rice farming system
1) First scenario (the goat price decrease): During 2021-2027 (7 years) plot margin of farm will decrease 69,397 Baht in total.
2) Second scenario (adjustment): The farmer decided to stop the feeding of goat concentrate and instead supplemented with fermented oil palm leaves and oil palm frond. During 2021-2027; the farmer earned a margin of farm 1,616,008 Baht in total or 226,747 Baht on average which can compensate for the lower margin of farm under first scenario (the goat price decrease) (Figure 11).
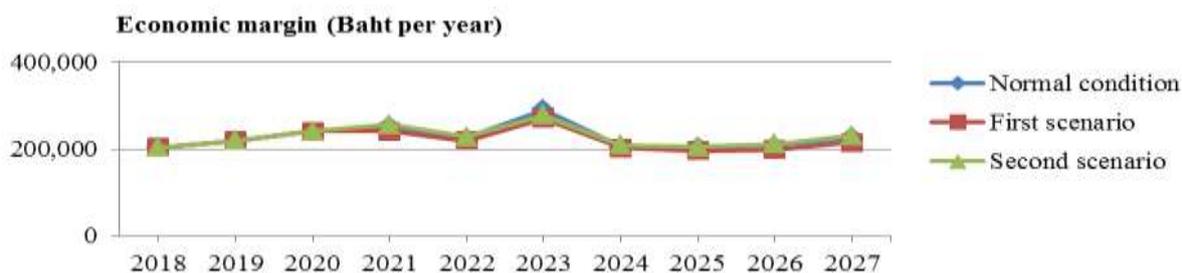]

Figure 11 The economic margin of Plot 4 before and after simulation

Plot 5 the raising goat along with rubber trees and sweet-corn farming system
1) First scenario (the goat price decrease): During 2021-2027 (7 years) plot margin of farm will decrease 95,751 Baht in total.

2) Second scenario (adjustment): The farmer decided to stop the feeding of goat concentrate and instead supplemented with fermented sweet-corn. During 2021-2027; the farmer earned a margin of farm 1,157,622 Baht in total or 161,626 Baht on average which can compensate for the lower margin of farm under first scenario (the goat price decrease). (Figure 12).
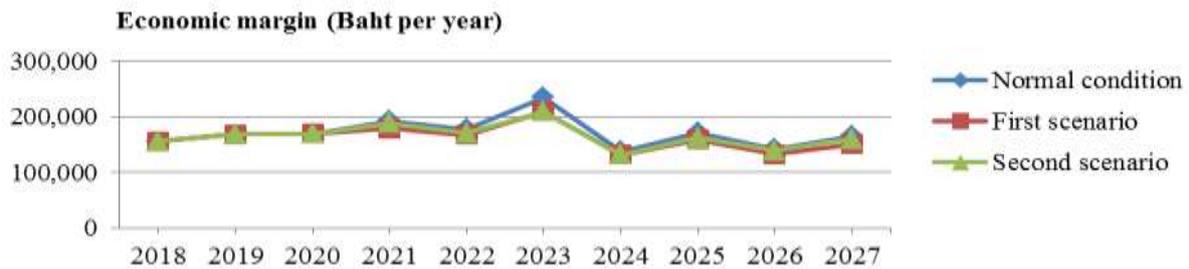

Figure 12 The economic margin of Plot 5 before and after simulation

Discussion and Conclusion

In terms of cost and benefits of five sample farm households in 2018 showed the margin farming system had different benefits because of some factors as a variable cost, goat breeder, cost of concentrate, cost of the fuel, cost of the chemical fertilizers, cost of labour, the cost of medicine, and cost of mineral. Jongrungrot and Thungwa (2014) Key factors influencing resilience levels are: quantities and types of intercropped timber, proper timing for cutting of timber, and efficiency in farm management by farmers to improve yields of intercropped fruit trees, and adaptation of other kinds of products in the farms to proliferate household income. The increased share of off-farm income could also be useful in reducing some adverse results of fluctuating rubber price and higher wage of farm labor. Somboonsuke et al. (2011) indicated that farmers who practice rubber mono-cropping systems had the lowest income and those practices rubber agroforestry system (RAFS) get a higher income, so the livelihood of RAFS farmers is improved. Jongrungrot (2014) had shown that (Rubber Agroforestry System) RAS is the most resistant to uncertainties and risks of economic fluctuation because various incomes were derived from various products of other plants and/or animals during the long none-tapping period of rubber trees as well as increasing more income during rubber trees harvesting. In conclusion, to increase the income and more effective labour, each farm should follow these recommendations; (1) Adaptation is needed to get rid of the marketing and price risk. For example (1.1) providing the proper amount of condensed food for the goats or replaced the condensed food with other cheaper protein nutrition such as Ruzi Grass, Soybean Meal, or gathering group to buy the ingredients to reduce the cost. (1.2) Using organic fertilizer or manure and chemical fertilizer to reduce the cost. (1.3) Adding more biological diversity in each farming system to get rid of the marketing and price risk (2) The farmers need to understand the breeder raising and using an appropriate factor of production due to the production results (3) Farmers have to consider the readiness and the cost of existing agricultural labor or labor to be hired in the future.(4) Farmers need to be developed in production, marketing, and optimize production performance and (5) Farmers must develop efficient animal production and an increasing number of goats/ family.

The farmers for this study are mostly smallholders who raise meat goats combined with plant cultivation. So, the farmers get mostly few incomes owing to some problems such as the small area, low budgets, agricultural knowledge limitation, and threats of goat raising are found as the lack of proper planning since the farmers raise goats as their supplement career. The agricultural patterns of the sample group are similar which are several types of cultivation combined with meat goat raising to give diversity and lessen the risk of a marketing term and the unstable price of the products. Thus goat raising has proved to be a

best integration in the farming systems because of its low operation cost and it can be an important source of income to compensate for the lower margin when rubber price is low. However, when goat price is also low the farmers can adjust management practices to offset lower margins.

Acknowledgements

References

Attonaty, J., Deheuvels, O., Grusse, P., Penot, E., and Snoeck, D. (2010). *Olympe farm (s) modeling and simulation tool.* Montpellier: CIRAD.

Chhiev, B., and Jongrungrot, V. (2021). Rubber agroforestry system (RAS) practices to overcome rubber price and soil erosion in Southern Thailand. *International Journal of Agricultural Technology, 17*(1), 13-32.

Finneran, E., Crosson, P., O'Kiely, P., Shalloo, L., Forristal, D., and Wallace, M. (2010). Simulation modelling of the cost of producing and utilising feeds for ruminants on Irish farms. *Journal of Farm Management, 14*, 93-117.

Finneran, E., Crosson, P., O'Kiely, P., Shalloo, L., Forristal, D., and Wallace, M. (2012). Stochastic simulation of the cost of home-produced feeds for ruminant livestock systems. *Journal of Agricultural Science, 150*, 123-139.

Gittins, P., McElwee, G., and Tipi, N. (2020). Discrete event simulation in livestock management. *Journal of Rural Studies, 78*, 387-398.

Jongrungrot, V. (2014). *The economic efficiency and social security of smallholder farming system which practices associate crops in rubber plots in Southern Thailand.* Ph.D. Thesis, Prince of Songkla University.

Jongrungrot, V., and Thungwa, S. (2014). Resilience of Rubber-based Intercropping System In Southern Thailand. *Advanced Materials Research, 844,* 24-29.

Pralomkarn, W. Supakorn, C., and Boonsanit, D. (2012). Knowladge in Goats in Thailand. *Walailak Journal Science and Technology, 9*(2), 93-105.

Satun Provincial Administrative Organization. (2018). *General data*. Retrieved from www.satunpao.go.th/general_data/?page=2.

Satun Provincial Livestock Office. (2018). *Statistics Report.* Retrieved from pvlo-sat.dld.go.th/webnew/index.php/th/service-menu/stat-report.

Somboonsuke, B., Wetayaprasit, P., Chernchom, P., & Pacheerat, K. (2011). Diversification of Smallholding Rubber Agroforestry System Thailand. *Kasetsart journal of social sciences, 32*, 327–339.

Suthammanon, S., Sirivongpaisal, N., Pallapat, P., and Rattana, V. (2011). *Supply chain management of goat industry in Satun province*. Retrieved from elibraly.trf.or.th/project_content.asp?PJID=RDG544008.