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Technical Efficiency and Meta technology Ratios of Rubber Farmers in Sub-Tropical Zones of Thailand

Research Article

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Abstract

In the sub-tropical zone of Thailand, the RRIM600 rubber clone is one of the most cultivated varieties due to its high productivity and high tolerance to drought conditions. In 2003, Para rubber producers embarked on the great rubber plantation expansion project. Since the project's commencement, the subtropical zone's production of the RRIM600 rubber clone has expanded to 1.4 million hectares in 2021. However, the spatial distribution of rainfall is one of the main limiting factors affecting productivity and farm management practices, including applying fertilizers, labor, chemical usage, and harvesting methods. In the interzonal and intertemporal rainfed zones. This paper aims to analyze the technical efficiency of rubber farmers in the high rainfed zone (HZ; more than 1,900 mm/year) and low rainfed zone (LZ; less than 1,650mm/year) and to compare the rainfed zone technology gap ratios (RTGR) for the different management practices from 2012 to 2015 using farm-level panel data. We found surprising results. The technology gap ratio indicated that LZ uses more suitable technology than HZ, although the agro-climate has a disadvantage. Particularly in the high rainfed zone, the adoption of intensive inputs usage is inappropriate technology in Para rubber plantations. For RRIM600, Para rubber strain with agro-climate advantages should be identified, and appropriate technology should be employed in high rainfed zone.

Keywords: Metafrontier, Rubber farming, Stochastic frontier analysis, Technology gap, Technical efficiency, RRIM600

JEL classification codes: Q12, Q16, Q18.

Introduction

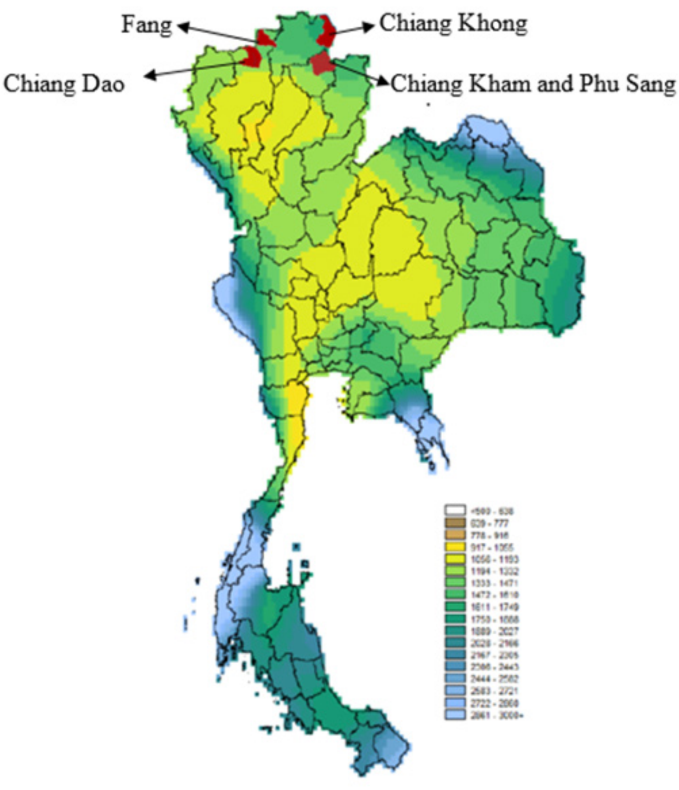
Thailand is the major natural rubber exporter, with one-third global market share. For this reason, most of the natural rubber is processed in the tire industry with high demand from major import countries such as China, India, the United States, Japan, and the European Union. Moreover, rubber farming is an important part driving Thailand's rural economy by being one of the most valuable agricultural commodities. Originally, Para rubber was mostly cultivated in Southern Thailand. Starting in 2003, the Thai government commenced a new project for inexperienced farmers to expand on arable land in sub-tropical zones where there was less rainfed than in Southern areas (tropical zone).Rubber farming in the sub-tropical zones of Thailand was intensively promoted in 2003-2008 by using RRIM600 rubber clones (more than 90%). According to Agricultural Statistics of Thailand (2019), expanding the planting area was successful in more than 1.40 million hectares of a new area (sub-tropical zone) and 2.13 million hectares of traditional area (tropical zone) in 2021. Meanwhile, India, Myanmar, Vietnam, and China also enlarged rubber farmings in the sub-tropical zone to 4.56, 2.64, 6.8, and 6.96 hundred thousand hectares, respectively.

Rubber farming has never grown in the sub-tropical previously. The project's inexperienced farmers were provided workshop training, sapling rubber trees (a clone of the RRIM600 rubber variety), soft loans, and preparation for panted RRIM600 rubber, which was appreciated for its drought-tolerant qualities and capacity to adapt to the environment as well as the project's major rubber species [1]. In general, promoting rubber farming in new environments could provide good yields relying on proper maintenance, well-organized farm management and effective technology for adaptation of RRIM600 to the environment of sub-tropical zones with less rainfall. There was still lower productivity than in the original zone [2]. The stimulus of rubber farming in the sub-tropical zone occurred during a period when the world demand for natural rubber dramatically increased due to China's automotive industry, causing the dry rubber price to be the highest average annual price in 2012 at 120 baht/kg. It dropped sharply to 66 baht/kg in 2020. Before that, between 2001-2004, average annual prices were only 20.52, 27.69, 37.76, and 44.13 baht/kg, respectivel. In addition to enthusiastically encouraging the price of dry rubber were caused inexperienced farmers in the new areas accepted risks and invested in rubber plantations.

Consistent with the Office of Industrial Economics or Research and Development Center for Thai Rubber Industry, the RRIM600 rubber variety is excellent drought-tolerant but few productive than the traditional area, roughly 10-30%. This prominent trait was related to an experimental plot in the sub-tropical zone of Buriram province, which found that the yield of 9-year and 10-year rubber trees were 36.9 and 45.7 kg/ha per year, respectively. There were several comparative productivity studies of rubber farmings in the sub-tropical zone with different rainfed. Sangchanda, et al. [3,4] studied the household level of rubber farming between RRIM600 and RRIT251 by comparing dry rubber yields in the northeastern region, including Sakon Nakhon, Nong Khai and Udon Thani. These provinces are adjacent to the great Mekong River, which influences water vapour in the air, turning into rain. Nong Khai had an average rainfed of more than 1,500 mm/year in 2013-2015. On the other hand, other provinces which had not been influenced by rainfed from the Mekong River, including Udon Thani, Buriram, Loei, and Khon Kaen had an average rainfed around 1,200-900 mm/ year, respectively. Consequently, the circumference of rubber trees and yield are related to the amount of rainfed.

Study Areas

Figure 1 from The National Agro-Economic Zoning for Major Crops in Thailand [5] showed that rubber farmings in the new areas receive less rainfed than the traditional areas in southern Thailand, more than 2,000 mm per year. This study in the upper northern region (red highlight areas) showed different rainfed regions in each district of Chiang Khong, Chiang Kham, Phu Sang, Fang, and Chiang Dao. Chiang Khong has the highest rainfed, which consequently gets more than 2,000 mm per year of rainfall, i.e. the high rainfed zone (HZ). Besides, the rest regions, including Chiang Kham, Phu Sang, Fang, and Chiang Dao are normal rainfall areas in the sub-tropical territory as the low rainfed area (LZ). Table 1 shows rainfall in each area during the study period, indicating that rainfall greatly fluctuates. As reported by the Northern meteorological centre (2017), there was a period of fluctuation and decreasing rainfall over a three-year production period, which showed highly variable rainfall. The humidity of the Mekong River influenced Chiang Khong district in Chiang Rai province. This famous waterway produced the most rainfall in 2013/14 at 2,480 mm per year. Additionally, its average rainfall amount is more than 1,900 mm per year, which is higher than in Phayao (Chiang Kham and Phu Sang districts) and Chiang Mai (Fang and Chiang Dao districts) at 1,570 and 1,176 mm per year, respectively. According to the Northern Meteorological Data Center, most study areas had an average of 120 rainy days per year. However, the amount of rain that rubber trees require in some areas and some years, for some years, the average annual rainfall was less than 1,250 mm per year in some areas. This occurrence might cause rubber trees to grow slowly, and farmers were unsatisfied with the outcome.



Source: FAO (2017)

Note: are study areas.

Figure 1: Rainfed zones in Thailand (Unit: millimetre per year).

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Variations in Output Produced and Inputs

The survey results using factors to compare the average of unit/ha are shown in Table 1, between High Rainfed Zone (HZ) in Chiang Khong and Low Rainfed Zones (LZ) in other districts. There are differences in some factors of HZ, which show greater results than LZ at 17.60% of production, 25.62% of labor and 9.55% of fertilizer value. This would indicate the difference in the use of inputs, even if we applied the same types of rubber variety (RRIM600) and product (dry rubber).

Certitude of Farmers 0n High Rainfed

Based on this survey, farmers in HZ stably relied on their particular farm management, which differed from the recommendations of the Rubber Research Institute of Thailand [1]. Farm management suitability in research plots for RRIM600 in the sub-tropical zone using a different technology between HZ and LZ is called the Rainfed technology gap. This ensured farmers had more benefits in greater rainfed than in other areas. Rubber farmers in HZ were convinced that the RRIM600 would increase yields with rainfall, drought tolerance and low incidence of bark disease. Therefore they had higher yield expectations than farmers in other zones. HZ farmers also invested in chemical fertilizer and adjusted their farm management with harvesting methods or tapping more frequently than the Rubber Research Institute of Thailand. However, this certain activity will lead to dry bark disease occurrence, which causes rubber trees to stop feeding latex for several months. Moreover, it may adversely affect the yield and growth of the rubber plant in the long term. However, it is recommended that to appropriate practice for the RRIM600, farmers follow this sustainable guideline to obtain efficient productivity over a 25-year harvest period [6].

Table 3 recommends the proper way to cultivate RRIM600 in the sub-tropical zone. The Rubber Research Institute of Thailand [1] has been experimenting with rubber farming in research plots in a new area (sub-tropical zone). This investigation advised farmers on user inputs and suitable farm management for the RRIM600. Considering phytodisease, the number of farms in which hay bark disease occurred in more than 10% of all trees in HZ farms. Moreover, there were differences between HZ and LZ farm management and farmers' characteristics for each cultivating area. Regarding most inexperienced farmers, there was no significant change in farm management practices over the study. There was only raising in the tapping area as the rubber trees had to be larger than 50 cm in diameter to start harvesting or tapping. The average rate per farm of annual open tapping area, i.e. farms 1, 2, and 3, were 69%, 82%, and 93%, respectively.

Although RRIM600 is highly resistant to frequent tapping, dry bark disease in HZ was still more than 58.97%. Almost farmers (92%) in the HZ employed the advantage of rainfed by too frequently tapping rubber with two days of tapping followed by one day rest, which is contrary to agency's agricultural extension recommendation that causes dry bark disease. The government organized workshop training to acknowledge inexperienced rubber farmers. The topographic factor of the HZ rubber farmings had a more than 15 degrees slope, more than 33%. The narrow planting distance of 3x6 m. in the LZ is more suitable for small rubber farming with sufficient labor. The previous study with technical efficiency on rubber farming did not have much panel data. In 2017, Malawal studied the technical efficiency of rubber farming by using panel data. There were also several types of research on technical efficiency with cross-section data Mustapha, et al. [7-10]. The study of Marian, et al. [11] employed stochastic production frontier and meta-stochastic production frontiers to compare different agri-climate. This investigation focused on adopting a potential environmental variation of rice meta-stochastic production frontiers to compare with technical efficiencies for each climatic zone in the Philippines. Kabubo Mariara, et al. [12] applied SFA to assess the overall farm efficiency and the influence of climatic, agroecological, and household factors on farm-level efficiency. In Geffersa, et al. [13] estimated meta-regression analysis from technical inefficiency scores estimates from primary frontier studies of Ethiopian crops across agroecological zones in the sub-sector from 1991–2015.

Accordingly, the study on the efficiency of rubber farming in agro-climatic zones where there were different rainfed amounts could indicate whether inexperienced farmers could manage their inputs productively. Moreover, the research could explain the factors to farmers, enabling them to manage their rubber farming effectively. We used Stochastic Frontier Analysis (SFA) to analyze inputs and determine the technologies at different rainfall zones in each zone, using Meta- Frontier to measure the technology differences. (Environment–Metatechnology gap Ratios). Regarding this study, we called Rainfed Meta Technology Gap Ratios (RMTG), deriving from the use of new technology in specific areas and the advantages and disadvantages of different rainfall.

Methodology

The current study adopted the metafrontier analysis proposed by O'Donnell, et al. [14] to clarify potential environmental heterogeneity in rubber production frontiers and to examine for comparable technical efficiencies for each climatic zone. Technical efficiencies were investigated through a single metafrontier, defined as the unrestricted technology set's boundary. A frontier function encompassing all group frontiers was known as the metafrontier production function. These group frontiers were the restrictions of constrained technology sets. The distance between the group frontiers and the metafrontier, as indicated by the restrictive nature of the production environment, was the efficiency measurement. The firms encountered different territories or continents and situations and faced different production opportunities. Each firm had the choice of using different techniques or methods of input-out combinations. This situation was called "technology set differences" O'Donnell, et al. [14].

We launched our investigation using the parametric stochastic frontier analysis following the framework of Aigner, et al. [15] The model introduced by Battese, et al. [16] was then employed to determine the factors associated with technical efficiency in time-varying. Estimating the metafrontier production function proposed by Bettese, et al. [17,14] used the concept of a metafrontier to compare the technical efficiency of firms that may be classified into different groups. The research also investigated the issues of technological change, time-varying technical inefficiency, multiple outputs, different efficiency orientations, and firm heterogeneity. Estimating the metafrontier production function proposed by Bettese, et al. [17,14] used the concept of a metafrontier to compare the technical efficiency of firms that may be classified into different groups. The research also investigated the issues of technological change, time-varying technical inefficiency, multiple outputs, different efficiency orientations, and firm heterogeneity. The measurement of technical efficiency was based on the output-oriented production frontier, which influenced variables on yield by farm management and technical efficiency. Additionally, time-varying and technology gaps were involved in the upper northern region of Thailand. Therefore, the Stochastic-met frontier Frontier Analysis (SFA-meta) relating to O'Donnell, et al. [14] was established to estimate the rubber production frontiers of different farmer groups and Meta-frontier analysis was applied to estimate the production technologies in different rainfed zones. A stochastic group-k frontier model is:

$$y\_it=f(x\_1it,x\_2it,\dots,x\_Nit,\beta\hat{}k)\ e\hat{}(V\_it\hat{}k-U\_it\hat{}k) \qquad (1)$$

Where x_{Nit} is the *n*th input quantity of the *i*th firm in the *k*th is time period is an unknown parameter vector associated with the *k*th Group the v_{it}^{k} represents statistical noise and assumed to be independently and identically distributed as truncation (at zero) $N(0,e_{vk}^{2})$as random variables); and the u_{it}^{k} represents inefficiency and is defined by half

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normal distributions. The technical efficiency of the *i*th firm in the *t*th period with respect to the group-k frontier can be obtained using the result:

$$TE_{it}^{k}=y_{it}/e^{(x_{it}'\beta_{it}^{k}+V_{it}^{k})}=e^{(-U_{it}^{k})} \quad (2)$$

The stochastic translog production frontier function is given by equation (1) where u_{it}^{k} represent the technical efficiency of the ith and kth groups, $\beta_{ij}=\beta_{ji}$ to satisfy the concavity property of the translog function. The format is:

$$\ln[y_{it}]=\alpha_0+\sum_{i=1}^{N}[\beta_{it}^{k}\ln[x_{it}^{k}]]+1/2\sum_{i=1}^{N}\sum_{j=1}^{N}[\beta_{ijt}^{k}\ln[x_{it}^{k}]\ln[x_{jt}^{k}]+]\beta_{it}^{k}D_{it}^{k}+v_{it}^{k}-u_{it}^{k} \quad (3)$$

Regarding estimate frontier by separated inputs and outputs of firms in the kth group can be used to obtain either least-squares or maximum-likelihood (ML) estimates of the unknown parameters of this frontier. Where y_{it} is output; dry rubber (kg.) x_{Nit} are inputs; land, fertilizer, labor, chemical, plant spacing, harvesting, dry bark disease and times. The technical efficiency variables; age, tapping area, training, slope area, plant spacing, outsourced labor and times. O'Donnell, et al. [14] also provide an econometric estimation of the metafrontier parameters using stochastic frontier analysis. To estimate the metafrontier, we need to find the function that best envelops the deterministic components of the estimated stochastic group frontiers (frontiers for rainfed zones in our analysis). Formally, the Metafrontier production function is:

$$y_{it}^{*}=f(x_{1it},x_{2it},\ldots,x_{Nit},\beta)=e^{(x_{it}'\beta)} \quad (4)$$

Where y_{it}^{*} it is the metafrontier output, and β is a vector of metafrontier parameters satisfying the

Constraint $x_{it}'\beta \geq x_{it}'\beta_{i}^{k}$ for all k = 1,2,…,K

for all k = 1,2,…,K

It can be calculated as the ratio of observed output to the corresponding stochastic frontier output given inputs, existing technologies, and environmental conditions after estimating the stochastic frontier production function for each of the rainfed groups:

$$TE_{it}^{k}=\frac{y_{it}^{k}}{f(x_{it},\beta^{k})e^{(-U_{it}^{k})}}=\exp(-u_{i}^{k}) \quad (5)$$

The metatechnology ratio (MTR) for the ith firm in the tth period (in the kth group)

$$RMTR_{it}^{k}=e^{(x_{it}'\beta^{k})}/e^{(x_{it}'\beta)} \quad (6)$$

The technical efficiency of the metafrontier is the ratio of the observed output according to the frontier output that adjusts for the corresponding random error. In practice, it is convenient to predict technical efficiency with respect to the metafrontier using the decomposition:

$$T[E_{it}^{*}=TE]_{it}^{k}\times RMTR_{it}^{k} \quad (7)$$

Dataset

This study used a panel dataset from a survey of natural rubber production in provinces of the upper northern region. Questionnaires were employed and investigated from 175 households of farmers during the production year 2012- 13- 2014/ 15. A total of 525 samples were collected by multi-stage random sampling. The researchers randomly selected the provinces with the highest number of farmers in the upper northern region. Also, they chose the district with the highest density of rubber farming in HZ, Chiang Rai District, Chiang Rai Province. These areas were high rainfall and were influenced by the Mekong River water vapour. In the LZ as low rainfall districts are the Chiang Kham and Phu Sang districts of Phayao province Fang, and Chiang Dao districts of Chiang Mai province.

According to the Office of Agricultural Economics [18] data, Chiang Rai's natural rubber production volume was 56.2 thousand tons, 84. 25 per cent of the total production of natural rubber in the eight upper northern regions, including Chiang Rai, Phayao, Chiang Mai, Lampang, Lamphun, Mae Hong Son, Phrae and Nan. Table 4 shows the trend on average yields and inputs of rubber farmings in the study area, which tend to be in the same direction for both LZ and HZ. The increased productivity was related to a longer life span of rubber trees yield in the study area (9-11 years). Farmers decreased investment in fertilizer use due to the declining price of natural rubber production. They preferred low-cost fertilizer but still followed the Department of Planting Promotion recommendation. Dry bark disease was more likely to occur due to improper tapping.

Table 5 shows individual characteristics and different farm management between HZ and LZ, i.e. pooled, which is used to estimate the technical performance of rubber farming for inexperienced farmers. The results showed that the number of farms in which hay bark disease occurred was more than 10% of all trees in HZ farms. Moreover, there were differences in farm management methods; rubber tapping (two days in tapping followed by one day rest = 1, otherwise = 0) where HZ was 38.65% more frequent tapping pattern than the other ones. Regarding the main phyto disease, i.e. dry bark disease, which disrupts dry bark yield (affected with yield more than 10% = 1, fewer = 0), it was shown that HZ was greater than LZ at 58.97%. Additionally, there were still differences in environment and farm management, including workshop training (attended at least once = 1, never =0) and slope area on the farming field (slope more than 15 degrees = 1, fewer = 0). Outsource labor was hired by owners of rubber farms doing other main occupations such as merchants, civil servants and officers (employing outsource labor = 1, unemploying = 0), and plantation space 3x7 and 3x6 meter.

This study estimated rubber farming efficiency in the upper northern provinces, which separated the estimation areas according to different rainfed zones. Based on the technological difference test by likelihood ratio test (LR- test), it was found that rubber farming in Chiang Rai had different technologies compared to Phayao and Chiang Mai as the result of rainfed zones affecting conditions. For this research, we employed the maximum-likelihood estimations of the parameters in each rainfed zones [19]. Furthermore, the methods of O 'Donnell et al. [14] were used to estimate the meta-frontier to compare technical performance, spatial Agri-climate and technology differences gap.

The Result of the Production Frontier Estimated

To confirm differences in technology for each group. Therefore, hypothesis testing ensured that each group had no difference from the pooled model. Also, two rainfall zone groups were compared by the likelihood ratio test and Chi-square statistic, LR-test = -2[(LLFHZ+ LLFLZ) - LLFpooled)] at 135.892, which was greater $X_{(0.01,28)}^{2}$ than , the outcome revealed that this critical value was 48.278, causing the main hypothesis to be rejected. It showed that there are technical differences between different rainfall zones. To make the performance estimation more accurate, it is worth estimating the metafrontier model and testing the existence of technical efficiency and suitability between the Translog production function and Cobb-Dunglas production function. The LR- test found the presence of inefficiency, and the Translog production function is a production function that is suitable for estimating each production frontier. Table 6 shows the maximum- likelihood estimates of the stochastic frontier production model by rainfed zones. The coefficients of independent variables between the pooled model and group frontiers were relatively in the same direction, with the most statistically significant positive effect on the yield factor. This variable was fertilizer, which resulted in a 0. 317 per cent increase in yield for every 1 per cent increase in each input. Followed by the tapping area, the yield increased by 0. 312 per cent for every 1 per cent increase in each tapping area. The negative factors affecting the bark were dry bark disease and the planting spacing of 3x6 m.

The study of Sanraksaraksawong [6] was adopted to interpret this sample case's time variables. The RCCTRI (2011) results were conducted in the field trial without changing farm management and any other inputs. It was shown that the time variable influencing yield increases with the natural growth of rubber trees at age 9-11 years, not by any technological addition under constant use of inputs. The rusults indicated that proper tapping positively influenced rubber tree growth in LZ due to less frequent tapping. For returns to scales, only HZ is greater than 1, however; these values remained close to 1 in both HZ and LZ models. Consequently, they could be more reasonable than the pooled model.

Table 7 shows the results of estimating the technical efficiency of 3 models, comprising the HZ model, the LZ model, and pooled model. The table showed the effect of variable inefficiencies from the Translog model estimation, revealing that pooled model farms with large tapping areas had more inefficiency than small farms, and outsourcing labour negatively affected the inefficiency. This consequence was come from employing specialists to manipulate rubber farms. Considering the group-specific efficacy between HZ and LZ, the age of the farmers proposed a positive sign indicating that the variable positively influenced the inefficiency of rubber farming due to its labor-intensive. Moreover, plant spacing is 3x6 m. showed a positive influence on the area. Although there were many trees per area, HZ farmers were still enabled to manage their cultivating area well. Previous participation in workshop training had affected reducing inefficiency, which was important to inexperienced rubber planters. The slope area increased the inefficiency significantly, indicating that rubber planting on the slope area needed constantly improved performance.

Regarding specific farm management, two days in tapping followed by one day rest reduced the inefficiency in the lifespan of the tree over time, which is related to farm management that requires unnecessary additional labor. The timing variables influenced HZ district inefficiencies, implying high yield expectations and improvements in farmers' technical efficiency. Overall, the coefficients of the inefficiencies variables tended to be in the same direction. Additionally, these values were more reasonable in the statistically significant variables from spatial estimation that uncontrollably separated factors from both rainfall and farm management behaviour of farmers in specific areas.

Technical Efficiency and Rainfed Metatechnology Ratio

Table 8 shows technical efficiency estimates for specific groups and pooled datasets, considering the use of niche farm management and technology gaps. The pooled dataset's mean technical efficiency was 0. 746, indicating the level of achieving output production was only 75 %of total input utilization. Segregation groups that draw out the advantages of spatial rainfed and actual farm management, in particular, the HZ and LZ groups, had 0. 633 and 0. 507 less productivity than the overall average production. It had a relatively low-efficiency level, with an average technical efficiency of 63% and 50% of total input utilization.

The rainfed metatechnology ratio in Table 8 indicates the degree of technological use in different environments in each rainfed zone. When comparing each region with markedly different use of inputs and outputs, we found that LZ carried out better technology utilization at 0.729, while it was 0.676 in HZ. Therefore it was indicated that LZ employed better farm management for rubber varieties; RRIM600. This rubber breed represented a farm management model recommended by the Rubber Research Department as an appropriate technology. As technical efficiency respected with the metafrontier eliminated environmental advantage and applied different farm management technologies, it was found that rubber farming was at the average level of technical efficiency in the upper northern region (0.405). Spatial considerations showed that the HZ region had greater efficiency than the LZ at 0.435 and 0.395.

The results above suggested that the conductance of rubber farming and technology was insufficient to provide suitable rubber farming in each area. However, farm management was good against RRIM600. On the HZ part, farmers possessed their comprehension of rainfall. Therefore there was a lack of alternatives to using other rubber varieties. Additionally, understanding the pros and cons of each farm management may intensely limit the RRIM600 cultivation that requires proper farm management for long-term production. Table 9 shows the annual trends on the mean of technical efficiencies obtained from the group frontiers and the metafrontier. Overall, the technical performance of the pooled model of TE was 0.74 when being separated from the peer group with the time involved in the base year 2012/13. The HZ and LZ models were lower regarding technical production efficiency under specific environmental conditions and farm management in the H segment. There was a significant increase in production potential at TEg and TEm, with an average change of 6.19%, and 6.23%, respectively indicated that HZ had been advanced in farm management technology while Rainfed-Metatechnology Ratios of High Rainfed zone (RMTRHZ) increased by 1.83% over time. The RRIM600 had slightly adapted to different farm management. The LZ segment had reduced production potential at TEg and TEm. The average change was -1.27% and -2.93%, respectively. However, farm management technology was applied effectively under existing environments with an average RMTRLZ of 0.73% in the production year 2014/15, indicating LZ employed proper farm management technology and could improve technical efficiency.

Implications of Results

Estimating the technical efficiency of rubber farming in the upper northern region based on the pooled model showed that farmers possessed good performance in cultivation. However, separating spatial estimates with different rainfed by dissipating differences in agro-climate and farm-out management indicated that the farm management technology of HZ was inferior to LZ's estimation, despite its rainfall advantage. Although the HZ area showed improvement over time, LZ proposed a decline in technical efficiency.The decomposition of rainfed-metatechnology ratios of the high rainfed zone, which possessed specific farm management depicted the sources of inefficiency caused by either inefficient operations or disadvantageous conditions or by both.

Inefficient Operation

The rainfed metatechnology gap demonstrated that the inefficient operation of HZ compared to LZ showed greater inappropriateness for farm management to apply the RRIM600 clone following the recommendations of the Rubber Research Institute of Thailand [1]. As a result, the excess labor and bark disease increased over time.

Disadvantageous Condition

The influence of rainfed has contributed to benefits for RRIM600 in certain conditions [4]. The RMTR of LZ estimation indicated that the technology was appropriate for manipulation and showed good adaptability of the RRIM600 in the LZ region. However, farmers still needed to operate proper farm management and provide alternative rubber strains for specific rainfall [20-24].

Concluding Remarks

Estimating the technical efficiency of rubber farming in the upper northern region by separating districts by using rainfall, a factor affecting yields and beyond control. Including managing different farms based on the assumption of climatic advantages. Inexperienced farmers necessitate practical knowledge and suitable technology to cope with diverse sub-tropical regions. Consequently, this results in inappropriate use of technology from counting on the advantage of rainfed. Additionally, there were not many option varieties of rubber trees for farmers. However, some perennials could provide a yielding period of 25 years. The consequences of improper technological use will be demonstrated in the future.

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