Land Use Efficiency and its Change of Vietnam Based on DEA

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Abstract. Data envelopment analysis was used to analyze the land use efficiency of Vietnam and its six regions in 2011-2017, and then the Malmquist index was used to investigate the changes of the land use efficiency of Vietnam and its six regions and 63 provinces and cities in 2011-2017. The study found that the overall land use efficiency in Vietnam is low and there are serious regional imbalances, but the overall situation is improving year by year.

1. Introduction
Land provides indispensable space and resources for human survival and development, and land resources are scarce. In 2014-2018, Vietnam's GDP grew at an average annual rate of 6.55%, one of the fastest growing economies in the world [1]. The spatial expansion of the city and the adjustment of industrial layout will further increase the demand for land. In 2018, Vietnam’s urbanization rate reached 36%. The Ministry of Construction’s “2012-2020 National Urbanization Development Goals” proposed “strive for the number of cities in the country to reach 870 and the urbanization rate to reach 38% by 2015; by 2020, the number of cities will reach 940, achieving an urbanization rate of 45 percent.” [2] The acceleration of the urbanization process will inevitably lead to a growing contradiction between the protection of cultivated land and the land input required for urbanization. Therefore, studying the utilization efficiency of land in Vietnam has important practical significance for improving its land use efficiency, saving land resources, and achieving sustainable development of economy, society and environment.

The research on land use efficiency has been widely valued by scholars at home and abroad. Many scholars have applied different methods to researching and innovating the index system of land use efficiency from different angles. There are no studies on land use efficiency in Vietnam in the existing research, and they are mainly concentrated in a single city. There are few studies on land use efficiency in multiple cities and regions. Therefore, this paper takes Vietnam as the research object, and uses the Malmquist index and data envelopment analysis method (DEA) to evaluate the land use efficiency of 63 provinces and cities in Vietnam, in order to provide reference for the efficient and sustainable use of local land.

2. Vietnam overview

2.1 Geographic location
Vietnam is located in the eastern part of the Central South Peninsula with a land area of 329,000 square kilometers. Vietnam has a long and narrow terrain, S-shaped, with a maximum length of about 1,640 kilometers from north to south, about 600 kilometers at the widest point of the east and west, and only
50 kilometers at its narrowest point. The terrain is high in the northwest and low in the southeast. Three-quarters of the territory is mountainous and plateau, and there are two great plains, the Red River Delta and the Mekong Delta. The north and northwest are high mountains and plateaus. The rivers in Vietnam are densely covered, with 2,860 rivers with a length of more than 10 kilometers [3]. Vietnam's coastline is 3,260 kilometers long, with more than half of the 63 provinces and cities facing the sea, and many natural harbors with considerable importance.

2.2 Administrative division
Vietnam has 5 municipalities directly under the central government and 58 provinces, divided into 6 regions by region, namely the Red River Delta, the Northern midlands and mountain areas, the North Central and Central coastal areas, the Central Highlands, the South East, and the Mekong River Delta. The information is shown in Table 1.

| Region                        | List of municipalities and provinces                                      | Area (km²) |
|-------------------------------|------------------------------------------------------------------------------|------------|
| Red River Delta               | Ha Noi, Vinh Phuc, Bac Ninh, Quang Ninh, Hai Duong, Hai Phong, Hung Yen, Thai Binh, Ha Nam, Nam Dinh, Ninh Binh | 21259.6    |
| Northern midlands and mountain areas | Ha Giang, Cao Bang, Bac Kan, Tuyen Quang, Lao Cai, Yen Bai, Thai Nguyen, Lang San, Bac Giang, Phu Tho, Dien Bien, Lai Chau, Son La, Hoa Binh | 95222.1    |
| North Central and Central coastal areas | Thanh Hoa, Nghe An, Ha Tinh , Quang Binh, Quang Tri, Thua Thien-Hue, Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khoang Hoa, Ninh Thuan, Binh Thuan | 95871.9    |
| Central Highlands            | Kon Tum, Gia Lai, Dak Lak, Dak Nong, Lam Dong                                | 54508.3    |
| South East                    | Binh Phuoc, Tay Ninh, Binh Duong, Dong Nai, Ba Ria-Vung Tau, TP. Ho Chi Minh | 23552.6    |
| Mekong River Delta            | Long An, Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Dong Thap, An Giang, Kien Giang, Can Tho, Ha Giang, Soc Trang, Bac Lieu, Ca Mau | 40816.3    |

There are 729 cities in Vietnam, including 5 municipalities, including Hanoi, Ho Chi Minh City, Haiphong, Da Nang and Can Tho. Hanoi is the capital and the political and cultural center of the country. Ho Chi Minh City is the country's largest port city and economic center with the population ranking first in the country. Haiphong is an important port city in the north and the third largest city. Da Nang is an important port city in the central region with abundant tourism resources. Can Tho is an important political, economic and cultural center.

2.3 Natural resources
Vietnam is rich in resources and diverse in variety. Vietnam is rich in crops such as rice, corn, rubber, coconut, pepper, cashew, coffee and fruit. The forest area is about 10 million hectares. Vietnam has abundant fishery resources.

2.4 Population Distribution
In 2017, the total population of Vietnam was 93.7 million, of which male population was 46.2 million, accounting for 49.3% of the total population; female population was 47.5 million, accounting for 50.7% of the total population. The urban population accounts for 35.1%, and the rural population accounts for 64.9%. The labor force is 54.8 million, accounting for 58.5% of the total population. The average age of the Vietnamese is 31 years old. Vietnam's population was ranked 14th in the world, with a population density of 311 people per square kilometer [1].
3. Research methods and data sources

3.1 Data Envelopment Analysis method
Data Envelopment Analysis (DEA) is an analytical method for evaluating the relative efficiency of multi-factor inputs and outputs between Decision making units (DMU). It does not need to assume the weight of the indicators and the specific functional relationship [4]. This study selects the BCC model and uses an input-oriented DEA model.

3.2 Malmquist index
When the time factor is added to the DEA model, in the case of dynamic analysis, it is difficult to measure due to differences in production frontier surfaces at different times. In order to solve this problem, Malmquist proposes the Malmquist index. By analyzing the input and output result sets of the same DMU in different periods, the productivity change of DMU is obtained.

3.3 Indicator selection
The land use efficiency is characterized by the relationship between the input factors such as land and the labor carried by it in a specific time and space situation and the economic and social benefits it generates. Taking into account the representativeness of the evaluation indicators, the data accessibility and the characteristics of the DEA analysis method, the land and labor are selected as input indicators, and the land area and the number of laborers over 15 years old are selected to measure respectively. In terms of output, economic output and social output are selected as indicators, per capita monthly income and population density are selected to measure.

3.4 Data sources
The data used in this paper are the relevant data of 63 provinces, cities and 6 regions in Vietnam in 2011-2017, all from the Vietnam Statistical Yearbook (2011-2017).

4. Analysis of land use efficiency in Vietnam

4.1 Overall situation of land use efficiency in Vietnam
With the BCC model of DEA and input oriented, DEAP 2.1 software is used to calculate the comprehensive technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of land use in the six regions of Vietnam in 2011-2017, as shown in Table 2.

| Years | Region | TE   | PTE  | SE   | Returns to Scale |
|-------|--------|------|------|------|-----------------|
| 2011  | Red River Delta | 1.000 | 1.000 | 1.000 | Unchanged       |
|       | Northern midlands and mountain areas | 0.065 | 0.104 | 0.624 | Irs             |
|       | North Central and Central coastal areas | 0.034 | 0.045 | 0.752 | Irs             |
|       | Central Highlands | 0.056 | 0.072 | 0.769 | Irs             |
|       | South East | 0.228 | 0.726 | 0.314 | Drs             |
|       | Mekong River Delta | 0.134 | 0.134 | 0.999 | Unchanged       |
|       | MEAN | 0.253 | 0.347 | 0.743 |                  |
|       | Whole Country | 0.032 | 0.034 | 0.956 | Irs             |
| 2012  | Red River Delta | 1.000 | 0.032 | 1.000 | Unchanged       |
|       | Northern midlands and mountain areas | 0.065 | 0.766 | 0.624 | Irs             |
|       | North Central and Central coastal areas | 0.034 | 0.177 | 0.752 | Irs             |
|       | Central Highlands | 0.056 | 0.175 | 0.769 | Irs             |
|       | South East | 0.228 | 0.177 | 0.314 | Drs             |
|       | Mekong River Delta | 0.134 | 0.810 | 0.999 | Unchanged       |
### Table 2: Comprehensive Technical Efficiency of Land Use in Vietnam

| Year | Region                                      | MEAN  | MEAN  | MEAN  | Status       |
|------|---------------------------------------------|-------|-------|-------|--------------|
| 2013 | Red River Delta                             | 1.000 | 1.000 | 1.000 | Unchanged    |
|      | Northern midlands and mountain areas        | 0.062 | 0.106 | 0.588 | Irs          |
|      | North Central and Central coastal areas     | 0.030 | 0.042 | 0.727 | Irs          |
|      | Central Highlands                           | 0.052 | 0.071 | 0.739 | Irs          |
|      | South East                                  | 0.226 | 1.000 | 0.226 | Drs          |
|      | Mekong River Delta                          | 0.122 | 0.124 | 0.983 | Drs          |
|      | MEAN                                        | 0.249 | 0.391 | 0.711 |              |
|      | Whole Country                               | 0.030 | 0.031 | 0.963 | Irs          |
| 2014 | Red River Delta                             | 0.066 | 0.156 | 0.424 | Irs          |
|      | Northern midlands and mountain areas        | 0.270 | 0.282 | 0.957 | Irs          |
|      | North Central and Central coastal areas     | 0.321 | 0.623 | 0.514 | Drs          |
|      | Central Highlands                           | 0.006 | 0.390 | 0.016 | Irs          |
|      | South East                                  | 0.038 | 0.163 | 0.234 | Irs          |
|      | Mekong River Delta                          | 0.077 | 0.138 | 0.560 | Irs          |
|      | MEAN                                        | 0.130 | 0.292 | 0.451 |              |
|      | Whole Country                               | 0.099 | 0.103 | 0.963 | Irs          |
| 2015 | Red River Delta                             | 0.064 | 0.111 | 0.580 | Irs          |
|      | Northern midlands and mountain areas        | 0.270 | 0.282 | 0.957 | Irs          |
|      | North Central and Central coastal areas     | 0.321 | 0.623 | 0.514 | Drs          |
|      | Central Highlands                           | 0.006 | 0.390 | 0.016 | Irs          |
|      | South East                                  | 0.038 | 0.163 | 0.234 | Irs          |
|      | Mekong River Delta                          | 0.077 | 0.138 | 0.560 | Irs          |
|      | MEAN                                        | 0.130 | 0.292 | 0.451 |              |
|      | Whole Country                               | 0.099 | 0.103 | 0.963 | Irs          |
| 2016 | Red River Delta                             | 0.273 | 1.000 | 0.273 | Drs          |
|      | Northern midlands and mountain areas        | 0.349 | 0.685 | 0.510 | Drs          |
|      | North Central and Central coastal areas     | 0.116 | 0.157 | 0.736 | Irs          |
|      | Central Highlands                           | 0.208 | 0.292 | 0.713 | Irs          |
|      | South East                                  | 0.342 | 1.000 | 0.342 | Drs          |
|      | Mekong River Delta                          | 0.225 | 0.225 | 0.998 | Unchanged    |
|      | MEAN                                        | 0.252 | 0.560 | 0.595 |              |
|      | Whole Country                               | 0.044 | 0.061 | 0.718 | Irs          |
| 2017 | Red River Delta                             | 1.000 | 1.000 | 1.000 | Unchanged    |
|      | Northern midlands and mountain areas        | 0.051 | 0.063 | 0.805 | Irs          |
|      | North Central and Central coastal areas     | 0.034 | 0.042 | 0.821 | Irs          |
|      | Central Highlands                           | 0.047 | 0.071 | 0.661 | Irs          |
|      | South East                                  | 0.260 | 0.493 | 0.528 | Drs          |
|      | Mekong River Delta                          | 0.103 | 0.113 | 0.911 | Drs          |
|      | MEAN                                        | 0.249 | 0.297 | 0.788 |              |
|      | Whole Country                               | 0.049 | 0.185 | 0.264 | Drs          |

As can be seen from Table 2, from 2011 to 2017, the lowest value of the comprehensive technical efficiency of land use in Vietnam is 0.030 in 2013 and 2015, and the highest value is 0.099 in 2014. It is far from the effective standard of DEA. Subdivided into major regions, only the comprehensive
technical efficiency of land use in the Red River Delta has reached DEA in most years, and the average technical efficiency of the six regions has never exceeded 0.260. Scale efficiency is the decisive factor for technical efficiency. Only the Red River Delta can reach the DEA efficiency, and the Mekong River Delta has reached an optimum level of more than 90%. The Northern midlands and mountain areas, the North Central and Central coastal areas have reached an optimal level more than 80% in 2017.

In 2017, the Red River Delta not only achieved the best technical efficiency, pure technical efficiency and scale efficiency, but also the scale returns remain unchanged, indicating that the scale has been achieved. Both the South East and the Mekong River Delta are diminishing returns to scale, indicating that it is necessary to reduce the scale of investment in these areas, and the reduction in scale will contribute to the increase in output; the Northern midlands and mountain areas, the North Central and Central coastal areas, and the Central Highlands are all increasing in scale, indicating that these areas need to be expanded. The larger the scale, the more output.

4.2 Trends in land use efficiency in Vietnam

The Malmquist index model was used to investigate the changes and classification of land use efficiency in Vietnam and its six regions in 2011-2017. The results are shown in Table 3.

Table 3. Trends in land use efficiency across Vietnam and across regions. (2011-2017)

| Region                        | effch     | techch    | pech       | sech      | tfpch     |
|-------------------------------|-----------|-----------|------------|-----------|-----------|
| Whole Country                 | 1.071     | 1.151     | 1.327      | 0.807     | 1.233     |
| Red River Delta               | 1.000     | 1.600     | 1.000      | 1.000     | 1.600     |
| Northern midlands and mountain areas | 0.960     | 1.144     | 0.920      | 1.043     | 1.099     |
| North Central and Central areas | 1.003     | 1.142     | 0.988      | 1.015     | 1.145     |
| Central Highlands            | 0.973     | 1.148     | 0.998      | 0.975     | 1.117     |
| South East                    | 1.022     | 1.382     | 0.937      | 1.091     | 1.413     |
| Mekong River Delta            | 0.957     | 1.308     | 0.972      | 0.985     | 1.252     |

Among them, effch indicates the change of technical efficiency, and the value greater than 1 represents the improvement of technical efficiency, while the technical efficiency decreases when less than 1; techch represents technological change, and the value greater than 1 represents technological progress, and less than 1 represents technological regression; pech indicates pure technical efficiency change, the value greater than 1 indicates an increase in the level of application of the technology, and a decrease is less than 1; sech indicates a change in scale efficiency, the value greater than 1 represents an optimization of scale, and the value less than 1 indicates a deterioration in scale; tfpch indicates a change in land use efficiency, and the value greater than 1 indicates an improvement in efficiency, while less than 1 is a decline in efficiency [5].

From the overall level of the country, during 2011-2017, technical efficiency, pure technical efficiency and land use efficiency have been improved, technology has made progress, and scale efficiency has declined from the perspective of each region, the overall situation of land use efficiency in the Red River Delta, the north central and central coastal regions, and the southeast region is better than that of the other three regions, and the technologies in the six regions are improving, and the land use efficiency is improving.

The Malmquist index model was used to examine the changes in land use efficiency in 63 provinces and municipalities in Vietnam in 2011-2017. The results are shown in Table 4.

Table 4. Index of change in land use efficiency in Vietnam in each year (2011-2017)

| Period     | effch     | techch    | pech       | sech      | tfpch     |
|------------|-----------|-----------|------------|-----------|-----------|
| 2011-2012  | 1.426     | 0.826     | 1.705      | 1.020     | 1.178     |
| 2012-2013  | 0.687     | 1.547     | 0.587      | 1.171     | 1.063     |
| 2013-2014  | 1.818     | 0.752     | 1.674      | 1.086     | 1.367     |
| 2014-2015  | 0.747     | 1.499     | 0.600      | 1.245     | 1.120     |
From the perspective of year by year, the technical efficiency in 2011-2012, 2013-2014 and 2015-2016 increased slightly, mainly due to the increase in scale efficiency; the technical efficiency decreased in 2012-2013 and 2014-2015, mainly because of the decline in pure technical efficiency; the decline in technical efficiency in 2016-2017 is due to the decline in scale efficiency. Taken together, land use efficiency has increased in all years.

5. Discussion and suggestion

Through the study of land use efficiency and its changes in six major provinces and 63 provinces and cities in Vietnam, the following conclusions and inspirations are drawn:

First, at present, the overall land use efficiency in Vietnam is low. The land use efficiency of the Red River Delta is better in the six major regions. Among the other five regions, the land use efficiency in the western plains area is the worst. Vietnam’s land use efficiency shows extreme regional imbalances.

Second, the status of land use efficiency in Vietnam is improving year by year.

Third, the most important factor affecting the change of land use efficiency in Vietnam is the scale efficiency. It is necessary to give full play to the scale effect of central cities and effectively improve the ability of intensive land use.

Fourth, the land system is a relatively complex system. Due to the limitation of data availability, the index system designed in this paper cannot exhaust the influencing factors of land efficiency in Vietnam. The design of land use efficiency index system requires more theoretical methods and empirical research to enrich.

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