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Full Length Research Paper

Balance of rice for the Mekong Delta - Viet Nam to 2050 in terms of industrialization and climate change

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Rice area of the Mekong Delta (MD) has decreased in recent years, especially the shift from rice land into industrial land and saline land due to sea level rise and effects of climate change. In addition, the population growth rate also requires increasingly high demand for rice in the region. By using the dynamic modelling, results showed that the population will be at 26,956.5 thousand inhabitants, paddy land is 993.9 thousand hectares, rice balance will achieve 4729.9 thousand tons in 2050. Scenarios of sea level rise show that the sea level rise to 0.3 m in 2050, corresponding to the rice area is reduced by 0.6 million hectares, the paddy land remained only 851.6 thousand hectares, balance rice reached 2.6 million tons. Although rice yield increased due to intensive investment, the rate of declining rice land due to climate change and industrialization led to rice balance in 2050 only was 2.5 million tons. This is a huge pressure to national food security in the near future. So the strategy set for the MD in the near future is to stabilize rice area, slowing population growth and application of scientific and technical measures to improve productivity and rice output.

Key words: Rice land, population, rice output, industrialization, climate change.

INTRODUCTION

Mekong Delta is one of the most fertile deltas of Southeast Asia and the world. It plays a significant role in the area of production and export of food and it is the biggest orchard of Vietnam. The region is famous as a large rice growing area. It produces about half of the total of Vietnam's rice output. Vietnam is the second largest exporter of rice globally after Thailand (Kuenzer, 2012). In fact, the delta produces more rice than Korea and Japan combined (Gebhardt et al., 2012). Annually, being a low-lying coastal region, the Mekong Delta is particularly susceptible to floods resulting from rises in sea level due to climate change and nearly 50% of the area was flooded from 3 to 4 months which creates the regional features. On the one hand, it poses enormous challenge for cultivation, planting and makes life increasingly difficult for the people who live there. Incidentally, this sideline has created favorable conditions for fishing, aquaculture and adds fertility to the cultivated land.

Today, the region has become home to a large aquacultural industry of basa fish, Tra catfish and shrimp, much of which is exported (Moder et al., 2012).

The advantage of large population (17.21 million in 2009), an abundant labour force, fertile soil and stable climate has created favourable conditions for rice production in the Mekong Delta. However, agriculture in general and rice cultivation in particular is spontaneous, fragmented, scattered, and heavily influenced by the industrialization process, the rate of population growth and climate change. According to the Ministry of Agriculture and Rural Development, from 2000 to 2007, rice area decreased to an average area of 21,000 hectares per year. The land is recovered mainly for the construction of urban, industrial and other projects. With the speed of the current land acquisition, it is estimated that in 2020 paddy land in the country will be about 3.4 million hectares, while in the long term the risk of reducing rice land in the Mekong Delta and some coastal areas will be very high especially when faced with the sea level rise. Questions about the supply of rice, rice

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output supply for the region from now until 2050 with the role of ensuring food security for all countries in the context of population growth, climate change and industrialization have been set for this study. The objective of this study was to find out the main agricultural resources, rice output and food security for the Mekong Delta by 2050.

RESEARCH METHODOLOGY

Secondary data sources used in the study were obtained from the Department of Agriculture and Rural Development, Department of Statistics, Department of Planning and Investment, Department of Science and Technology of the provinces in the region. Primary data were collected through household surveys from 540 rice farmers in the study area. Data sources were used to run Cobb-Douglas function, and the factors affecting the yield as well as the distribution of the rice area were considered.

Factors affecting productivity are basic inputs, and these indirectly affect the total rice output and rice supply variable in the dynamic equilibrium model.

This research used the dynamic modelling by Bruce et al. (1994) to consider the change of socio-economic phenomenon in the long time. The relationship between these three main variables in the model (population-agricultural labour, cultivated rice, internal rice demand and supply equilibrium) will bring dynamic relationships over time. Population fluctuations depend on the birth rate, mortality rate, migration, and immigration.

Growth in population leads to increase in the labour in rice production activity, increase rice output for consumption, and the need to increase the paddy land for housing. Paddy land is directly affected by climate change and industrialization.

Outside these two factors, rice supply of the Mekong Delta is also affected by other factors such as fertilizer, labour, consumption in the region, and exchange rate outside the region.

RESULTS

Status of rice production in Mekong Delta

With the role of ensuring national food security and export, rice production in the Mekong Delta over the years had gained considerable improvement. The region's rice yield is higher than the national average and continues to grow over the years, thanks to the high intensive cultivation. Within the period of 2007 to 2009, average yield rose to 2.15%, output increased to 4.72% (Vietnam Statistical Yearbook, 2010).

Mekong Delta's agricultural area is the largest in the whole country. After the success gained in reclaiming several lands, making the most of unused land, plus investment in the exploitation of irrigation, application of technical measures aimed at increasing the coefficient of land use. Thus, paddy land tends to increase in all three crops. However, the effects of industrialization and the process of economic restructuring in the sector have continued; these will make the region's rice area decline markedly. Meanwhile, in the long-term, reduction of arable land in the Mekong Delta and some coastal plains is very high when facing the sea level rise. According to the Ministry of Agriculture and Rural Development, just 1 m sea level rise, will have up to 70 to 80% of the land submerged. Therefore, to maintain the role of ensuring food security for the country, according to the Mekong Delta Rice Institute, from 2010 to 2030, Mekong Delta has to stabilize annual rice area from 1780 to 1880 million hectares (Ministry of Agriculture and Rural Development, 2009).

Analysis of the changes of elements in the model

In the original script of the model, actual values of the elements obtained from the secondary resources from the provinces and the primary data through farmers survey were used.

The trend of population and labour changes

Results showed that the population of the Mekong Delta in 2050 would continue to increase. In 2010, the region's population was 17.4 million people; in 2030 it will be 21.7 million and will be reaching 26.9 million in 2050. Research results also showed that agricultural labour and labour involved in the production of rice continues to increase in absolute terms, but the structure tends to decrease. This is entirely consistent with the trend of the industrialization and modernization process and economic restructuring going on strongly today.

The trend of cultivated rice changes

The conversion of agricultural land into the socio-economic development objectives is taking place on a national scale with rapid speed. As reported by the Ministry of Agriculture and Rural Development, from 2000 to 2007, paddy land decreased 361.935 hectares, fell nearly 51.705 hectares per year on average where the Red River delta decreased 52.047 hectares and Mekong Delta was 205.366 hectares reduction (Ministry of Agriculture and Rural Development, 2009). Parallel to the process of industrialization and urbanization, the effects of climate change has taken place strongly. This greatly influenced the agricultural production in general and rice production in particular. Currently, when the effects are

Table 1. Rice production on Mekong Delta period 2007 to 2009.

Unit	Unit	2007		2008		2009		Average		
		Output	Ratio (%)	Output	Ratio (%)	Output	Ratio (%)	08/07	09/08	Ave.
1 Area	1000 ha	3683.1	100.00	3858.9	100.00	3872.9	100.00	104.77	100.36	102.54
- Spring Rice	1000 ha	1506.5	40.90	1526.5	39.56	1548.8	39.99	101.33	101.46	101.39
- Fall rice	1000 ha	1799.2	48.85	1939.8	50.27	1910.5	49.33	107.81	98.49	103.05
- Winter crop	1000 ha	377.4	10.25	392.6	10.17	413.6	10.68	104.03	105.35	104.69
2. Productivity	quintal/ha	50.7		53.6		52.9		105.72	98.69	102.15
- Spring Rice	quintal/ha	60.2		64.4		63.6		106.98	98.76	102.79
- Fall rice	quintal/ha	46.1		47.7		47.2		103.47	98.95	101.19
- Winter crop	quintal/ha	34.9		40.3		38.9		115.47	96.53	105.58
3. Output	1000 tons	18678.9	100.00	20669.5	100.00	20483.4	100.00	110.66	99.10	104.72
- Spring Rice	1000 tons	9072.4	48.57	9833.2	47.57	9856.1	48.12	108.39	100.23	104.23
- Fall rice	1000 tons	8291.1	44.39	9253.1	44.77	9018.2	44.03	111.60	97.46	104.29
- Winter crop	1000 tons	1315.4	7.04	1583.2	7.66	1609.1	7.86	120.36	101.64	110.60

Source: Statistical Yearbook 2010.

still low, the rate of loss of farmland due to urbanization and climate change was 1% (Ministry of Natural Resources and Environment, 2009).

According to the original script of the model, with the rate of loss of rice land by industrialization and climate change as today, the Mekong Delta's paddy land is 1619.8 thousand hectares in 2020 and only 993.9 thousand hectares in 2050.

Facts and the aforementioned analysis show that one of the plans to rice land use issue is to protect current agricultural land, taking measures to cope with climate change right now, considering the problem of industrialization and urbanization in a scientific, strict control of agricultural land in association with the overall planning of land use in other fields toward developing harmoniously agriculture and rural development (Table 1).

The trend of rice output changes

Rice output of Mekong Delta in 2050 tended to decrease. Since rice output is influenced by the yield, the total and sown area structure, therefore, rice yield could increase by an estimated 2.5% per year in 2020; the rate of decline of rice land moves quickly, so rice output is still declining. Specifically, as a result, rice output of the Mekong Delta is approximately 18 million tons in 2020. By 2050, this number will drop to more than 11 million tons.

Analysis of the relationship between population, cultivated land, and rice supply

The population of MD continues to grow while rice land tends to decrease along with the process of industrialization and climate change. Paddy land decreased from 1823.8 thousand hectares in 2010 down to 993.9 thousand hectares in 2050. From the rice production and distribution aspects, the goal of achieving highest food security in terms of rice amount in 2010 is the most appropriate time for the stabilization of rice land, not to decrease further. But with the national goal to become an industrialized country by 2020 with the rapid speed of industrialization, economic structure has shifting trend, the Mekong Delta need to expand, build more of industrial park, transfer inefficient rice land to aquaculture land. This change together with the effects of climate change make the rice production not balanced at the highest level that will reduce quickly.

Analysis of the change in population, cultivated land, rice output when other factors change

Variation in cultivated land and rice supply when sea level rises

Climate change has caused disasters in Vietnam increasing in number, intensity and extent of impact. According to "climate change scenario, sea level rise for Vietnam" by Ministry of Natural Resources and Environment made 06/2009, in the case of sea level rise by 1 m, the Mekong Delta will have 2 million hectares saline farmland that cannot be cultivated, which is mainly paddy land (Ministry of Natural Resources and Environment, 2009).

And according to this document, the results calculated by the low emission scenario showed that by 2050 sea levels would rise 0.3 m corresponding to 0.6 million hectares of Mekong Delta's rice land that will be flooded.

From 2000, rice land in the Mekong Delta reduced

205.000 hectares accounting for 57% of the country's rice land reduced at the same time (Party Central Office and the Ministry of Agriculture and Rural Development, 2009). This is mainly due to the recovery land of provinces for the construction of urban residential areas, industrial parks and many other buildings.

Last time, due to reclamation and restoration of land, rice sown areas are offset and expanded. However, the reclamation and restoration of land almost disappeared, while climate change and sea level rise could make Mekong Delta lose from 15,000 to 20,000 km^2 land, of which there are many rice sown area (Ministry of Natural Resources and Environment, 2009). From the aforementioned fact, the study assumed that the paddy land expansion rate decreased to 0.005%, rice land lost to rising sea levels was 1.500 ha/year (Table 2).

Results of scenario 1 showed that, the Mekong Delta's paddy land in 2050 is 851.6 ha; it is lower than the original plan of 142.3 ha. Rice output and rice demand-supply equiplibrium (D-S-E) therefore decrease 2.1 million tons, rice D-S -E only is 2.6 million tons in 2050. Assuming population growth rate does not change, this decline has great influence on the rice distribution for feed and exports. If the rice for export is lower by 260.9 thousand tons than original plan in 2020, by 2050 this number is more than 1 million tons. Therefore, to maintain the role of ensuring national food security and exports, the Mekong Delta need the technology measures to increase rice yields such as breeding new rice varieties, rinse the local rice varieties adapted to climate change, pest resistance, high yield, good quality rice, application of new measures to create mutations, gene transfer compound.

Changes in cultivated land and the demand and supply equilibrium of rice since paddy land transfer for industrialization is reduced

Recovery of agricultural land to use for the socio-economic development goals of the country recently went on massively. This is a necessity. However, according to Professor Logan (Logan University - Australia): "The use of agricultural land for urban development purposes and protection of agricultural land is a popular story, but in Vietnam today, this process occurs fastest in the world". Notably, the majority of agricultural land is recovered with good soil, for 2 rice crops per year. Meanwhile, rice land is irreplaceable and significant decision for national food security.

Article 74 of the Land Law 2003 stipulated: "State policy to protect paddy land, restricting transfer of paddy land to the use of non-agricultural purposes (The congress of Vietnam Socialist Republic, 2004). Where necessary to transfer a part of the area for rice cultivation to be used for non-agricultural purposes, the State shall take measures to supplement or enhance the area of land for rice cultivation" (Table 3).

To ensure food security for both domestic and export rice in the context of global climate change, the Ministry of Agriculture and Rural Development has planned from now to 2030, Mekong Delta has to stabilize an area of rice land 8 million hectares, and this region has to stabilize rice output per year from 19.5 to 21 million tons (Party Central Office and the Ministry of Agriculture and Rural Development, 2009). However, if rice land continues to reduce as current rate, the Mekong Delta will reduce more than 200,000 ha rice land, it means the reduction of 600.000 ha of rice sown area, equivalent to more than 3 million tons per year in 10 years. Meanwhile, the Mekong Delta's population and the country's are growing, demand food has also increased. Thus, according to experts, the Mekong Delta should not withdraw more paddy land for other purposes in addition to applying technical measures to increasing productivity and rice output. Accordingly, in this scenario 2 we assume that rice productivity will increase by 2.5%, coefficient of land use increased 2.3 times per year, the paddy land transfer for industrial purposes decreased from 21.000 ha per year down to 15.000 ha per year.

Results when there are changes showed that, paddy land and rice D-S -E tend to increase compared to the original plan. By 2050, rice land area increases to 246 ha and the rice D-S -E will increase more than 3 million tons. With constant population size, increase in rice D-S-E will lead to distribution for other purposes such as increased livestock and exports. The conditions for reclaimed land area are no longer the effects of climate change to agriculture taking place complicatedly; this increase is extremely important for Vietnam: the country is currently holding the second position in rice production in the world.

Changes in population, cultivated land, and rice D-S -E when there are changes of all factors

The aforementioned analysis shows that rice land area of the Mekong Delta is reduced by the impact of industrialization and climate change. To ensure food security and export demand, the region should apply intensive measures to increase rice productivity and rice output, reducing the rate of population growth. In this scenario, the research will consider the changes of rice D-S -E when there are simultaneous effects of factors in relation to changes in rice area due to industrialization and climate change; rice productivity and rice output increased; rate of population growth decreased.

Results of scenario 3 from aforementioned changes show that paddy land was lower than the original script for 361.6 thousand hectares (in 2050). Although rice land decreased by the process of industrialization, urbanization and the impact of climate change, increasing the coefficient of rice land from 2.1 to 2.3 times, increasing investments in rice production, rice output

Table 2. Comparing original scenario and scenario1.

Item	Unit	2020			2030			2040			2050		
		OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)
-Population	1000 people	19414.6	19414.6	0	21659.2	21659.2	0	24163.0	24163.0	0	26956.5	26956.5	0
-Paddy land	1000 ha	1619.8	1580.6	-39.2	1412.2	1339.4	-72.8	1204.0	1096.4	-107.6	993.9	851.6	-142.3
-Rice D-S –E	1000 tons	17425.3	16920.6	-504.7	13330.5	12292.0	-1038.5	9103.8	7531.5	-1572.3	4729.9	2623.7	-2106.2
-Distribution													
+ Feed	1000 tons	1742.5	1692.1	-50.4	1333.0	1229.2	-103.8	910.4	753.2	-157.2	473.0	262.4	-210.6
+ food	1000 tons	5242.0	5242.0	0	5848.0	5848.0	0	6524.1	6524.1	0	7278.3	7278.3	0
+ Export	1000 tons	9008.9	8748.0	-260.9	6891.9	6355.0	-536.9	4706.7	3893.8	-812.9	2445.4	1356.5	-1088.9

Source: Results of the model, Vietnam Statistical Yearbook, 2010. Original scenario: Expanded rate: 3.5%; land area lost due to sea level rise: 100 ha/year; Scenario 1: Expanded rate: 0.05%; land area lost due to sea level rise: 1500 ha/year.

Table 3. Comparing original scenario and scenario 2.

Items	Unit	2020			2030			2040			2050		
		OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)
-Population	1000 people	19414.6	19414.6	0	21659.2	21659.2	0	24163.0	24163.0	0	26956.5	26956.5	0
-Paddy land	1000 ha	1619.8	1684.8	65	1412.2	1538.2	126	1204.0	1390.0	186	993.9	1239.9	246
-Rice D-S –E	1000 tons	17425.3	21533.1	4107.8	13330.5	18084.1	4753.6	9103.8	14500.1	5396.3	4729.9	10765.3	6035.4
-Distribution													
+ Feed	1000 tons	1742.5	2153.3	410.8	1333.0	1808.4	475.4	910.4	1450.0	539.6	473.0	1076.5	603.5
+ food	1000 tons	5242.0	5242.0	0	5848.0	5848.0	0	6524.0	6524.0	0	7278.3	7278.3	0
+ Export	1000 tons	9008.9	11132.6	2123.7	6891.9	9349.5	2457.6	4706.7	7496.5	2789.8	2445.4	5565.7	3120.3

Source: Results of the model, Vietnam Statistical Yearbook 2010; Original scenario: Productivity growth rate: 0%; coefficient of land use: 2.1 times; cultivated land transfer for industrial land: 21000 ha; Scenario 1: Productivity growth rate: 2.5%; coefficient of land use: 2.3 times; cultivated land transfer for industrial land: 15000 ha.

therefore generally tends to increase compared to 1, 2 script.

The study also showed that growth speed of rice output tends to decrease gradually due to reduced levels of rice land for industrialization; urbanization and climate change was faster than the increase in rice yield due to application of intensive measures to increase rice productivity.

With population growth decrease, increase in rice output made paddy land per capital initially tends to increase on average; the amount of food for grain therefore reduces to nearly 1.2 million tons in 2050.

Especially, when socio-economic develop, human life is raised, and the average food per capita decline in economics law of Engel (assuming reduced from 270 kg /person to 240 kg /person), the distribution of grain for livestock, export and other purposes will increase. This is very significant in the process of industrialization and economics restructuring of the region (Table 4).

Thus, with the scenario of improving productivity and rice output by the application of intensive measures in terms of rice sown area tending to decline, with the assumption of average rice consumption/person decreases from 270 to 240

Table 4. Comparing original scenario and scenario 3.

Items	Unit	2020			2030			2040			2050		
		OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)	OS	S1	(+,-)
-Population	1000 people	19414.6	19100.1	-314.5	21659.2	20994.2	-665	24163.0	23076.1	-1086.9	26956.5	25364.5	-1592
-Paddy land	1000 ha	1619.8	1538.6	-81.2	1412.2	1249.1	-163.1	1204.0	947.4	-256.6	993.9	632.3	-361.6
-Rice D-S-E	1000 tons	17425.3	20356.5	2931.2	13330.5	14692.8	1362.3	9103.8	8752.9	-350.9	4729.9	2509.7	-2220.2
-Distribution				0			0			0			0
+ Feed	1000 tons	1742.5	2035.7	293.2	1333.0	1469.3	136.3	910.4	875.3	-35.1	473.0	251.0	-222.0
+ food	1000 tons	5242.0	4584.0	-658.0	5848.0	5038.6	-809.4	6524	5538.3	-985.7	7278.3	6087.5	-1190.8
+ Export	1000 tons	9008.9	10524.3	1515.4	6891.9	7596.2	704.3	4706.7	4525.3	-181.4	2445.4	1297.5	-1147.9

Source: Results of the model, Vietnam Statistical Yearbook 2010; Original scenario: Average paddy land/person: 270 kg; coefficient of land use: 2.1 times; Productivity growth rate: 0%; population growth rate: 1.1%, land transfer for Industrialization: 21000 ha; land lost due to sea level rise: 100 ha/year; expanded rate: 3.5%; Scenario 1: Average paddy land/person: 240 kg; coefficient of land use: 2.3 times; Productivity growth rate: 2.5%; population growth rate: 0.95%; land transfer for Industrialization: 15000 ha; land lost due to sea level rise: 1500 ha/year; expanded rate: 0.05%.

kg/year according to economic laws, the security of rice for the Mekong Delta in 2050 not only is ensured but also will be redundant for export.

However, this equilibrium can only be sustained if the Mekong Delta has timely measures to deal with climate change, adapting to the effects of sea level rise, controlling and planning of industrialization and urbanization most closely.

Conclusion

Through the study of rice D-S -E for Mekong Delta in terms of paddy land area decreased by climate change and industrialization and urbanization, the results allow the following conclusions:

1. The results of system analysis problem considered in 2050 took time, the period in the rice D-S -E was maintained with the current change of paddy land. Until that time, the population of the Mekong Delta will be at 26.96 million people, paddy land is 993.9 thousand hectares.

2. The results in scenario 3 are the most appropriate. Compared with other scenarios, rice output in scenario 3 is not peaked, but in this scenario, the rice D-S-E was 2.5 million tones. This not only ensures food security but also the need for livestock, export and other purposes. Besides, the increase in intensive investment for rice production was the cause of productivity and output growth, ensuring national food security and export.

3. The Mekong Delta is one of the great and fertile plains of Southeast Asian; it is the most important food production and export area of the country. In the future, when the possibility of reclaim is no more, climate change and sea level rise make losing a considerable amount of agricultural land, Mekong Delta should reduce paddy land move to industrialization and urbanization to ensure national food security and export.

4. The current consumption of the Vietnamese average was 270 kg of rice and 300 kg of food grain/person/year. In scenario 3, with the assumed average rice/person/year were 240 kg; the results showed that consumer demand for rice has declined the amount of grain for livestock and export increased significantly. Due to practical requirements on labour and employment, the region needs to have the strategies to promote livestock development to take full advantage of surplus grain production in the coming years.

5. Population and labour have close relationship. With the population growth rate of 1.1% annually, the Mekong Delta has to create jobs for hundreds of thousands of workers. This is a huge pressure for economic development of the region where up to 85.67% of the labour force is untrained (Vietnam Statistical Yearbook, 2010). So, the strategy of the population in the future is to stabilize population size and improve the quality of human resources. The calculation of the study is to reduce the rate of population growth from 1.1 to 0.95%; the population size should be maintained at 2564.5 thousand in 2050 to help ensure food security in terms of rice land which is declining due to the effects of climate change and

industrialization and urbanization.

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