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The Future of Rice Production, Consumption and Seaborne Trade: Synthetic Prediction Method

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The Synthetic Prediction Method (SPM) is used to determine the factors affecting the production, consumption and transportation of rice in Asia, Africa, Europe, the Americas, and Oceania. Rice deficits, surpluses, and balances are investigated worldwide. Attention is given to shortages of rice in Africa and how to alleviate them. The requirements for seaborne trade of rice from Asia to Africa are investigated and estimated.

Rice is the staple food for about one half of the world's population, and it supplies 20% of the calories consumed worldwide. The International Rice Research Institute (IRRI 2000) estimated food supplies relative to the population of the world and predicted that 800 million tons of rice will be required in 2025.

The Food and Agriculture Organization (FAO, 2000) estimated rice production and consumption for each country through 2005. However, long-term estimates were not made.

Tsujii (1997) devised a method to make accurate predictions regarding production and consumption, especially for Japan and China.

Yap (1997) conducted research on the main factors for production and consumption. He predicted worldwide rice consumption in developed and developing countries through 2010. In this paper, predictions for per capita consumption are made for developed countries. Production predictions are based on harvest area and yield per hectare. The focus of these predictions is on developing countries.

Schwartz (1991) showed that worldwide rice production and consumption were expected to grow at a slower rate in the 1990s than they did in the 1970s and 1980s. Her predictions dealt with rice consumption and Asian trade, and she demonstrated that Asian trade affects the worldwide rice trade.

These predictions all concerned worldwide rice production and consumption for rice-producing countries. Trade volume was estimated on the basis

of the difference in production and consumption. No attempt was made to predict the number of ships from each area that would be involved in the maritime transportation of rice.

The present study is based on rice production and consumption and supply and demand relative to several specific rice-growing areas of the world. In addition, 1998 population data from the United Nations and the U.S. were used to forecast consumption through 2030. Finally, worldwide calculations of surpluses, deficits, and requirements for the seaborne transportation of rice were undertaken. This study identifies the areas of rice scarcity, those of rice surpluses, and their balance. Ultimately, the focus of this study is to provide basic information concerning worldwide food with the goal of contributing to solve the looming food problem.

2004: The International Year of Rice

On 16 December 2002, the United Nations General Assembly (UNGA) declared 2004 the International Year of Rice to focus the world's attention on the role that rice plays in providing food security and poverty alleviation (FAO 2004).

These objectives are part of international development agreements among the United Nations Millennium Declaration, the Food and Agriculture Organization of the United Nations, the United Nations Development Program, the Consultative Group on International Agricultural Research Centers, and other organizations of the United Nations, including non-governmental organizations (UNGA 2002).

Worldwide Rice Outlook Through 2030

We use the Synthetic Prediction Method (SPM) to determine the factors affecting the production and consumption of rice in Asia, Africa, Europe, the Americas, and Oceania. Areas with rice deficits and surpluses are identified. Because about 40 years' worth of data are considered, it is possible to extend the predictions through 2030.

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As shown in Figure 1, if we try to treat this problem in every country, the annual change is drastic, making it difficult to approximate the tendency by a simple function. Since change is very sharp, the trend is predicted using many variables. The quantity of production is predicted for every country. Figure 2 shows the scheme of the International Food Policy Research Institute (IFPRI) model. Rice production is determined by the harvest-area and yield-per-hectare response functions. Yield per hectare is a function of the commodity price, the prices of labor and capital, technology improvements, and the growth rate of yield per hectare. The harvest area is a function of the past price, the prices of the other competing crops, and the growth rate of the harvest area. Annual production is estimated as the product of yield per hectare and harvest area. As shown in Figure 3, if the Analytic Prediction Method (APM) is used, these variables must also be predicted; therefore, they will become very complicated models. As shown in Figure 4, we overcame this problem by treating the subject on a continental scale. In this SPM, the annual production changes are smoother than those of APM.

Comparison of Prediction Values by APM and SPM

Fortunately, we can use the predicted results by the IFPRI. In order to make the comparison, the pre-

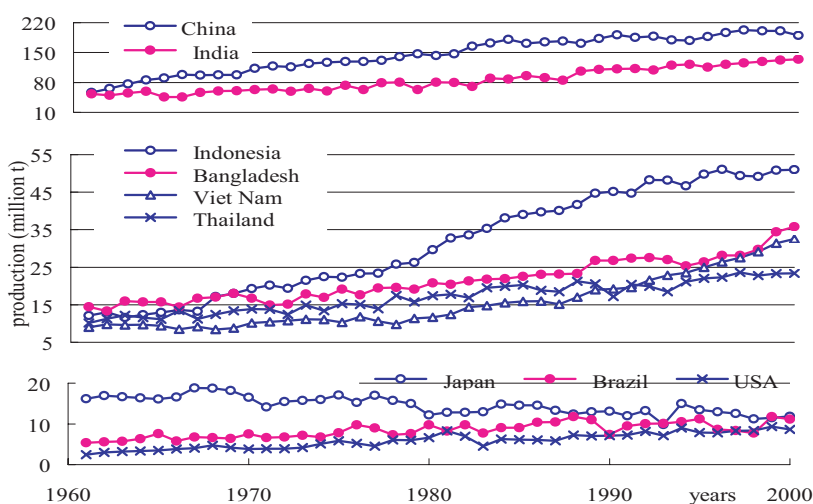
dicted data from 1991 to 2000 was used. As shown in Figure 5, we take APM and SPM into consideration; SPM is almost the same as the prediction by the IFPRI APM. Therefore, it appears that our model produces valid estimates.

Results of SPM

The consumption of rice in each region can be predicted using the SPM. This approach enables us to understand which areas are in deficit and which are in surplus.

Production is the product of the yield per hectare and the harvest area, so we tried to obtain their approximation equations. However, because the annual changes in the yield per hectare and the harvest area are drastic, as seen in the American example (Kubo and Purevdorj 2003), it is difficult to apply a simple function. Therefore, the year is adopted as a variable. The SPM regression analysis is performed for rice production, with the year as the explanatory variable.

The relationship between the population and rice consumption is approximated by simple-regression and multiple-regression curves. An approximating model for rice consumption was developed using population as a variable, and predictions were made. The equations for production and consumption for each area are



Source: Based on FAO, CD-Rom International Statistical, 2001. (Note: Rice is paddy)

Figure 1. Changes in Rice Production in Countries.

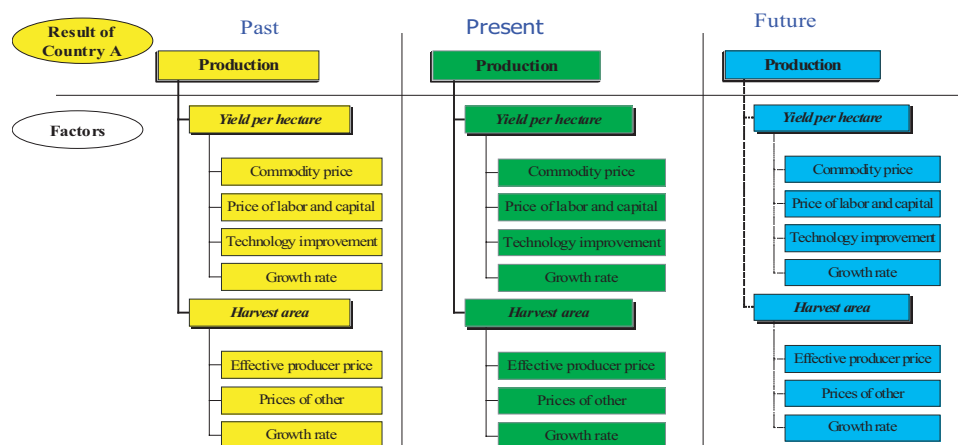


Figure 2. Analytic Prediction Method.

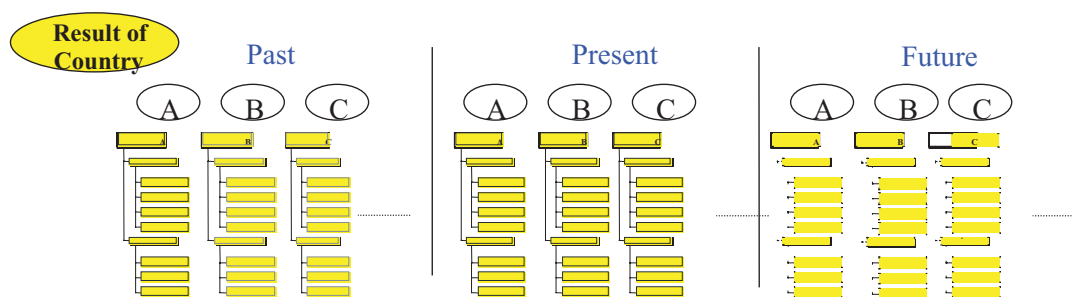


Figure 3. Analytic Prediction Method (APM).

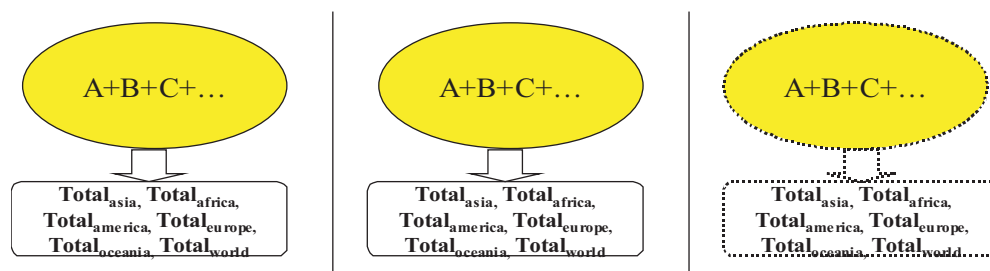
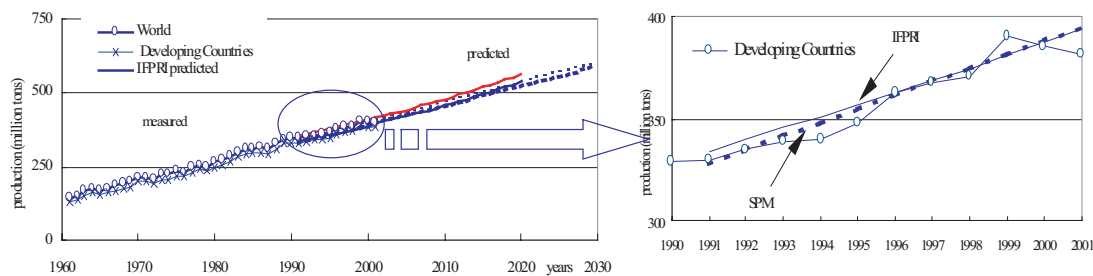


Figure 4. Synthetic Prediction Method (SPM).



Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent)

Figure 5. Comparison of Prediction values by APM and SPM.

$$1) \quad P_z(t) = a_z t - b_z$$

$$2) \quad C_z(t) = c_z POP_z(t) - d_z,$$

where $P_z(t)$ is area z 's production (million tons); t is the year; a , b , c , and d are the coefficients for area z ; $C_z(t)$ is the consumption of area z (million tons); and $POP_z(t)$ is the population of area z .

Equations of rice production, with the year as a variable, are shown in Table 1. The coefficients of determination and multiple-correlation coefficients are high. From this, the applicability of the model can be considered to be fairly good. The SPM regression results of consumption for each area are given in Table 2. As the coefficients of determination and multiple-correlation coefficients are high, the precision of the model is high. The model of the regression results is used in the following section.

Prediction Results of SPM

Predictions were made for rice production in each region using Equation (1). Worldwide rice production was 600 million tons in 2000; it is predicted to increase 1.5 times by 2030 to 904 million tons. According to the prediction, production in Asia will increase 1.5 times to 824 million tons; in the Americas, 1.4 times to 46.5 million tons; in Africa, 1.4 times to 24.8 million tons; and in Oceania, 1.3 times to 2.21 million tons.

By substituting the prediction value of the population into Equation (2), rice consumption through 2030 can be estimated for each region. The mean results for the predicted amounts of rice consumption are given below. Consumption in 2030 will be 1.6 times that of 2000, at 873 million tons. The International Rice Research Institute

Table 1: SPM Regression Results of Rice Production.

| Dependent Variables z | Coefficients | | t value | | R^2 | R |
|----------------------------|--------------|--------|---------|--------|-------|------|
| | a | b | a | b | | |
| World | 9.9746 | 19344 | 45.5** | 44.5** | 0.98 | 0.99 |
| Asia | 9.0403 | 17528 | 48.5** | 47.5** | 0.98 | 0.99 |
| America | 0.5173 | 1003.6 | 20.8** | 20.4** | 0.91 | 0.95 |
| Africa | 0.3025 | 589.3 | 18.3** | 17.9** | 0.89 | 0.95 |
| Oceania | 0.0317 | 62.08 | 17.3** | 17.1** | 0.89 | 0.94 |

**is the significant level of 1%.

Table 2: SPM regression results of rice consumption in each area

| Dependent Variables z | Coefficients | | t value | | R^2 | R |
|----------------------------|--------------|--------|---------|--------|-------|------|
| | c | d | c | d | | |
| World | 0.12289 | 149.45 | 51.7** | 13.1** | 0.98 | 0.99 |
| Asia | 0.1663 | 62.137 | 48.8** | 6.8** | 0.98 | 0.99 |
| America | 0.051 | 12.35 | 22.8** | 8.7** | 0.93 | 0.97 |
| Africa | 0.031 | 3.74 | 37.7** | 8.6** | 0.97 | 0.99 |
| Oceania | 0.0707 | 1.114 | 17.1** | 11.5** | 0.89 | 0.94 |

**is the significant level of 1%.

(IRRI 2000) predicts that 800 million tons of rice will be necessary in 2025; we predict 828 million tons, which is almost the same as the prediction by IRRI. Therefore, it appears that our model produces valid estimates.

Analysis of Prediction Results

This approach enables us to understand which areas are in deficit and which are in surplus. The predicted consumption and production amounts are given below. Self-sufficiency will continue in Asia, but an enormous shortage of rice is anticipated in Africa. The current deficit in Africa is 5 million tons; according to our prediction, it will reach 18 million tons in 2030. Although rice consumption will increase in the Americas and Oceania, these regions will continue to export rice.

Analysis of Surplus and Deficit

As shown in Table 3, the average annual population increase is predicted to slow down in Asia. In other words, the rate of increase in consumption in Asia will decrease in the future. Therefore, if production follows the current trend, a surplus will occur in Asia.

On the other hand, the average annual population increase in Africa will rise in the future. Therefore, if the production follows the current trend, the deficit will increase in Africa. The relation is shown in Figure 6.

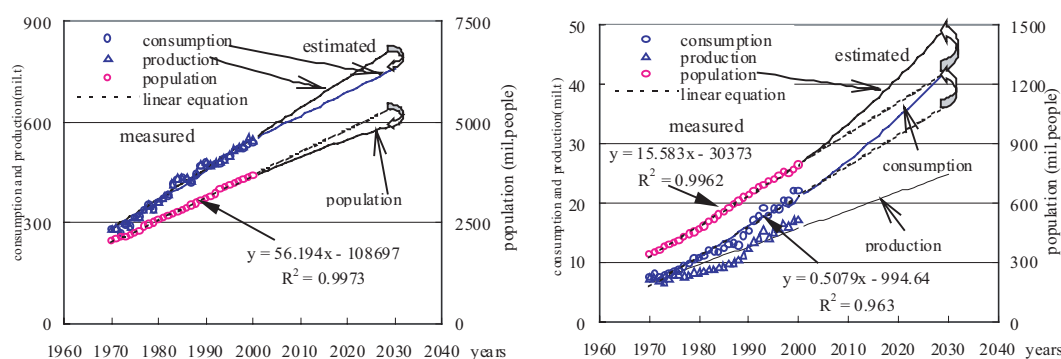
From Prediction to Planning

Our research has significantly clarified the issue of the surplus of rice in Asia and the deficit in Africa.

Table 3: Average Annual Increase in Population (millions).

| | 1970–2000 | 2000–2030 |
|--------------|-----------|-----------|
| Asia | 53.86 | 42.58 |
| Africa | 15.00 | 23.13 |
| The Americas | 10.73 | 9.53 |
| Worldwide | 80.83 | 73.76 |

Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent)



Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent)

Figure 6. Analysis of the Surplus and Deficit Volume of Rice and Population.

The trends for the surpluses in Asia and the deficits in Africa are shown in Figure 7. Self-sufficiency will continue in Asia, but an enormous shortage of rice is anticipated in Africa. The surplus of rice in Asia is much larger than that of the deficit in Africa, which is a very important finding. From the prediction result, if Asia decided to contribute to overcoming the deficit in Africa, the prediction results would be helpful to this end. However, such an undertaking would be beyond the scope of the present study. An international consortium of nations should agree it upon.

Rice Shipments to Africa

Seaborne Transport with SPM

Rice exports to Africa are examined using FAO data. Exporting countries were examined as well. As shown in Figure 8, Africa imports rice from America and Asia. In 2000, 24 importers in Africa imported 314,500 tons of rice from America, and 47 importers imported 4,343,000 tons from Asia.

Using data from the World-Wide Distance Chart and Admiralty Distance Tables (Lloyd's 1997) we

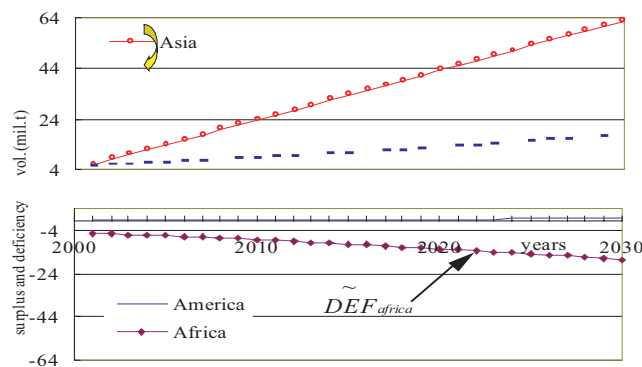
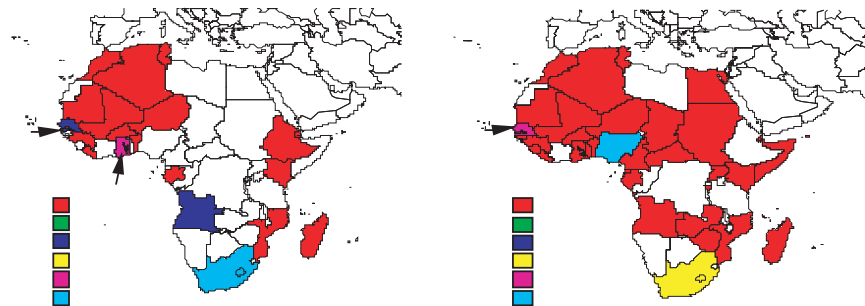


Figure 7. The Asian Surplus Can Compensate for the African Deficit.



Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent).

Figure 8. African Rice Importers in 2000 (1000 tons).

found the optimal navigation distance between export and import ports. Fifty-two countries imported rice in these 20 years in Africa. We think that the landlocked countries appear to have imported rice from neighboring countries with ports. Although many ports were located in each African country, 35 import ports were chosen for our analysis; the depth of each selected ports exceeds 10m (Kubo and Purevdorj 2004).

Figure 9 shows the seaborne trade W_{ij} from China and USA. Here, i is the exporter and j is the importer. The annual change is irregular. It is very difficult to predict the seaborne trade at this level, so we again use the SPM. If we bundle the importing countries from $j = 1$ to 35 in all African countries, the change of $\sum W_{ij}$ becomes rather smoother than that of former figure. However, the trend is still irregular. Figure 10 shows this change for Asian countries; they are all irregular.

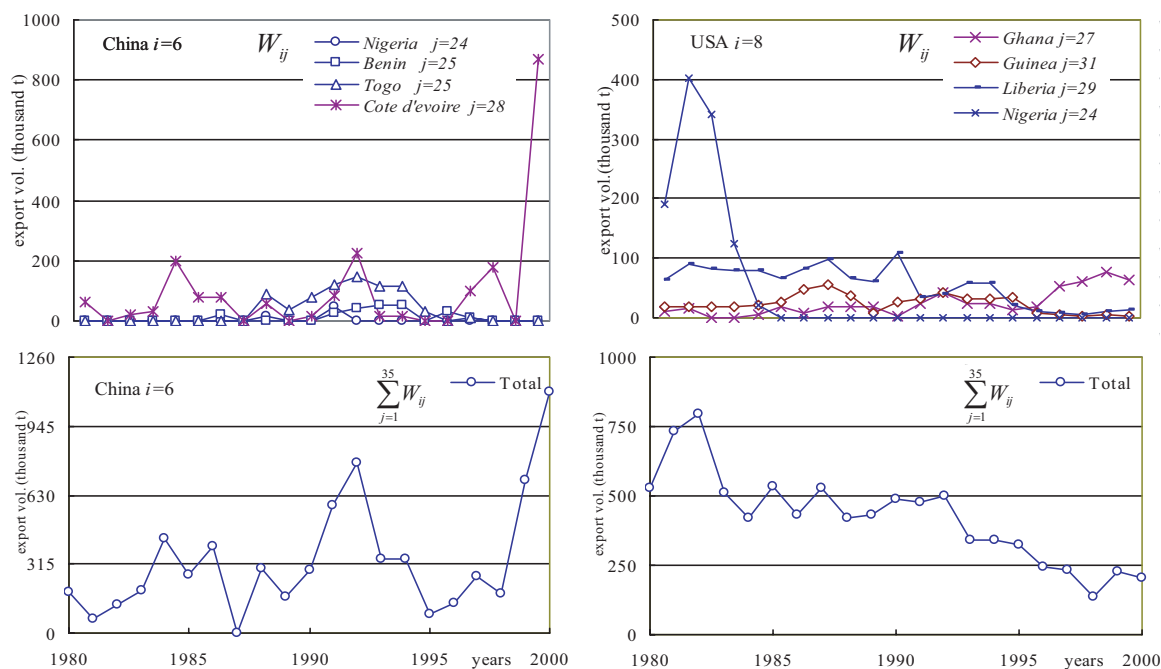
Figure 11 shows the seaborne trade $W_{ij}d_{ij}$. Here, d_{ij} is the distance from i country to j country, where the seaborne trades from China and USA are shown for example. The annual change is irregular, and it

is very difficult to predict the seaborne trade at this level, so we again use the SPM. If we bundle the importing countries, the change of $\sum W_{ij}d_{ij}$ becomes rather smoother than that of former figure. However, the trend is still irregular.

We bundle the exporting countries by each continent. The results are shown in Figure 12. This is the $\sum \sum W_{ij}$ and $\sum \sum W_{ij}d_{ij}$ for Asia and the Americas. Sigma i from 1 to 7 means all Asian exporters and sigma i from 8 to 10 means all the American exporters are bundled. We can see that the trend becomes very smooth and shows a clear tendency. In the following analysis, the navigation days of a vessel are considered to be 95% of 365. The navigation days, annual voyages, and necessary ships in the export navigation route from each exporter to an African importer were determined using the following equations under the SPM concept:

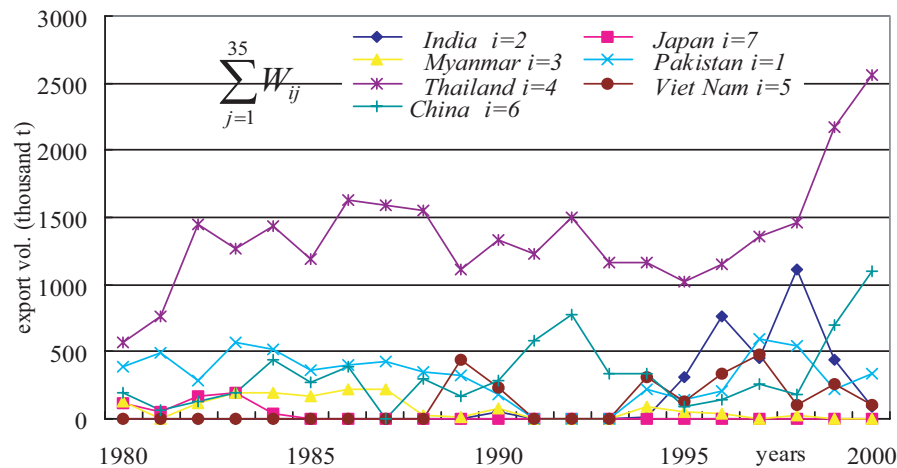
$$3) \quad D_{ij} = \frac{d_{ij}}{v \times 24} \times 2 + D_{ED} + D_{LU}$$

$$TS_{ij} = \frac{W_{ij}d_{ij} + W_{ij}A}{B},$$



Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent)

Figure 9. Change in Rice Import Volume.



Source: 1. Based on FAO, CD-Rom International Statistical, 2001 2. IFPRI, "Global Food Projections to 2020: Implications for Investment." October 1995. (Note: rice is milled equivalent)

Figure 10. Change in African Rice Import Volume from Asia.

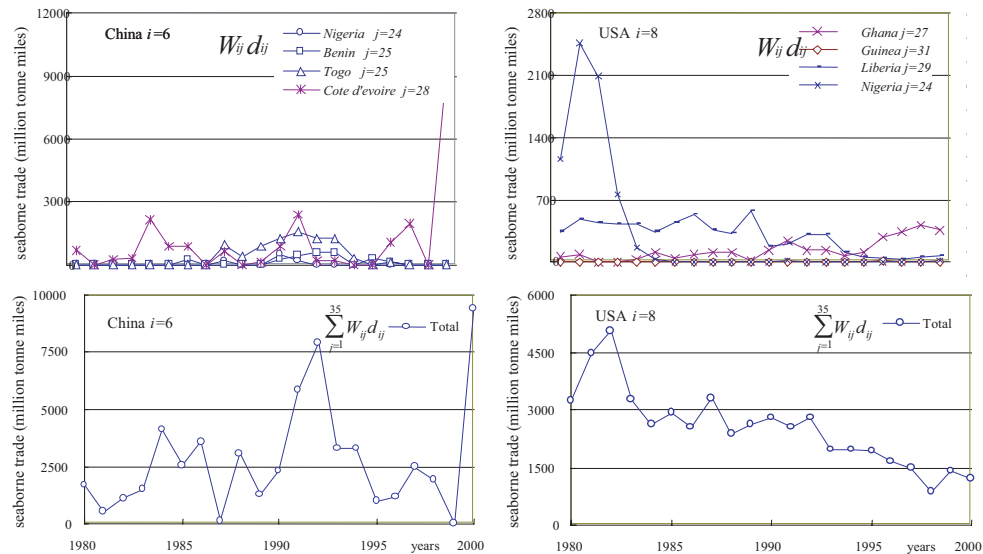


Figure 11. Change in Seaborne Rice Ttrade of Importer.

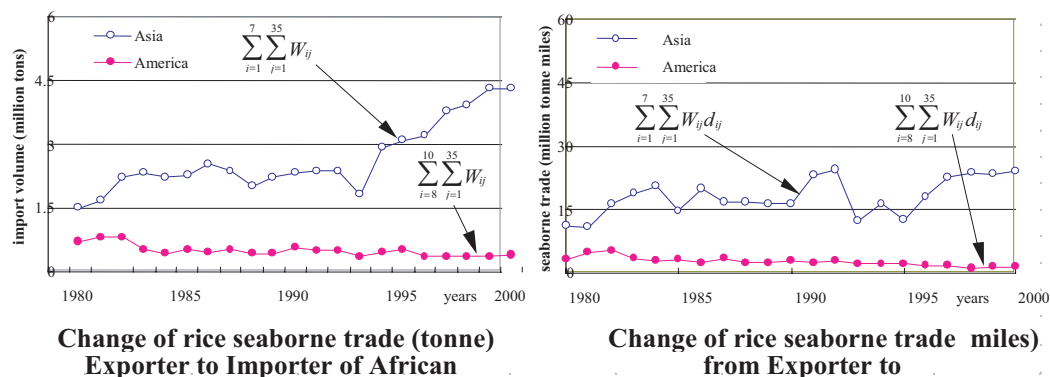


Figure 12: Seaborne Trade to Africa Using SPM.

$$4) N_{ij} = \frac{365 \times 0.95}{D_{ij}},$$

$$A = 72v, \quad B = DWT \times 4152v,$$

$$5) TS_i = \sum_j TS_{ij} = \frac{\sum_{j=1}^{35} W_{ij} d_{ij} + A \sum_{j=1}^{35} W_{ij}}{B},$$

$$6) TS_{ASIA} = \sum_{i=1}^7 TS_i = \frac{1}{B} \sum_{i=1}^7 \sum_{j=1}^{35} W_{ij} d_{ij} + \frac{A}{B} \sum_{i=1}^7 \sum_{j=1}^{35} W_{ij},$$

$$7) TS_{AMERICA} = \sum_{i=8}^{10} TS_i = \frac{1}{B} \sum_{i=8}^{10} \sum_{j=1}^{35} W_{ij} d_{ij} + \frac{A}{B} \sum_{i=8}^{10} \sum_{j=1}^{35} W_{ij}.$$

Here, i is the exporter, j is the importer, D_{ij} is the number of days necessary for a round trip from i to j , d_{ij} is the distance from i to the j area (miles), v is the speed of the grain bulk carrier (miles/hour), D_{ED} is the number of days required for entering and departing ports in one round trip (3 days), D_{LU} is the number of days required for loading and unloading in ports in one round trip (3 days), N_{ij} is the number of annual voyages of i and j , TS_{ij} is the number of ships for i and j , W_{ij} is the seaborne trade from i to j (tons), and DWT is the dead-weight tonnage of a grain bulk carrier (40,000 or 60,000 DWT).

SPM of Seaborne Trade in the Future

Future surpluses and deficits of rice are shown for each area in Figure 7. The African deficit is currently 5 million tons. According to the prediction, it will reach 18 million tons by 2030.

Estimates are made to determine how the African deficits will be managed. Asian filled 63% of the deficit in 1980, as shown in Figure 13. By 2000, Asia filled 90%, America filled 9.8%, and Oceania filled 0.1%. The exports from each area to Africa were estimated. Figure 13 shows the share of the export volume to the total seaborne trade. The definitions are given in the following equations:

$$8) ES_{asia} = \frac{\sum_{i=1}^7 \sum_{j=1}^{35} W_{ij}}{\sum_{i=1}^{10} \sum_{j=1}^{35} W_{ij}} \cdot 100$$

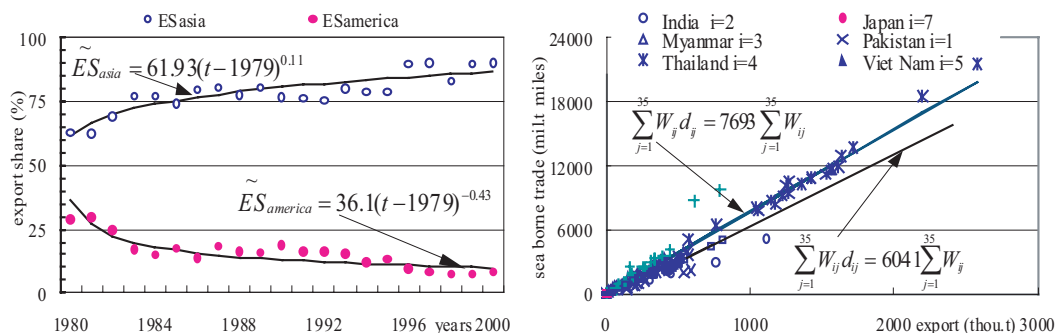
$$ES_{america} = \frac{\sum_{i=8}^{10} \sum_{j=1}^{35} W_{ij}}{\sum_{i=1}^{10} \sum_{j=1}^{35} W_{ij}} \cdot 100,$$

$$9) \begin{aligned} \tilde{ES}_{asia} &= 61.93(t - 1979)^{0.11} & R^2 &= 0.76 \\ \tilde{ES}_{america} &= 36.1(t - 1979)^{-0.43} & R^2 &= 0.71 \end{aligned},$$

$$10) \begin{aligned} \tilde{W}_{asia} &= \tilde{DEF}_{africa} \cdot \tilde{ES}_{asia} / 100 \\ \tilde{W}_{america} &= \tilde{DEF}_{africa} \cdot \tilde{ES}_{america} / 100 \end{aligned},$$

$$11) \begin{aligned} \tilde{W}d_{asia} &= 7693 \tilde{W}_{asia} & (i = 1 \sim 7) & R^2 = 0.76 \\ \tilde{W}d_{america} &= 6041 \tilde{W}_{america} & (i = 8 \sim 10) & R^2 = 0.76 \end{aligned},$$

Here, W_{ij} is annual transportation from i to j area (t); \tilde{ES}_{asia} and $\tilde{ES}_{america}$ are the future export shares (%) from Asia and America, respectively; \tilde{DEF}_{africa} is the deficiency volume in Africa; \tilde{W}_{asia} and $\tilde{W}_{america}$ are the future seaborne trade (million tons) from Asia and America, respectively; $\tilde{W}d_{asia}$ and $\tilde{W}d_{america}$ are the future seaborne trade (ton · miles) from Asia and



Sources: 1. Based on Lloyd's of London (1997). 2. Worldwide Distance Chart, Japan Navigating Officers Association, Kaibundo, 1990. 3. Admiralty Distance Tables, Volumes 1,2,3, The United Kingdom Hydrographic Office, NP 350(1,2,3). 4. Based on the same as for Figure 8.

Figure13. Share Of Rice Exports To Africa And Change Of Rice Seaborne Trade.

America, respectively; and t is the year. The volume of exports to Africa and seaborne trade (ton · miles) in the future are obtained using the SPM.

The results are shown in Table 4. By substituting the volume of transport to Africa into Equations (6) and (7), the number of required ships can be obtained. The import volume from Asia is 16.58 million tons, 94% percentage of the imports required in 2030. If we use 40,000DWT or 60,000DWT bulk carriers, 71 or 41 ships will be required. The volume of import from America is 1.05 million tons, a 6% share. Three or two ships (40,000DWT or 60,000DWT) are required for the transport.

Conclusion

We examine rice production and consumption by continent. If each research area were investigated separately, the annual change would be dramatic. From this, the applicability of the SPM to production, consumption, and maritime transport can be considered to be fairly good.

When we take APM and SPM into consideration, SPM is almost the same as the prediction by APM. Therefore, it appears that our model produces valid estimates.

Since the average annual increase in population of Africa is rising, the rice deficit is expanding. On the other hand, since the average annual increase in population in Asia may decrease, the volume of consumption may be reduced. For this reason, it is possible that a surplus will occur in Asia. The surplus will be sufficient to compensate for the shortfalls in Africa.

We found a good relation between transportation weight tons and weight-ton miles. This information was valuable for predicting the appropriate

number of ships required to transport surplus rice to Africa.

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Table 4: Seaborne Trade to Africa in the Future.

| years | Export volume (mil. tons) | | Seaborne trade (bil. ton · miles) | | Necessary ships (DWT) | | | |
|-------|------------------------------|---------|--------------------------------------|---------|-----------------------|--------|---------|--------|
| | Asia | America | Asia | America | Asia | | America | |
| | | | | | 40,000 | 60,000 | 40,000 | 60,000 |
| 2005 | 6.515 | 0.659 | 50.12 | 3.97 | 28 | 16 | 2 | 1 |
| 2010 | 8.386 | 0.389 | 64.51 | 5.07 | 36 | 20 | 3 | 2 |
| 2015 | 10.37 | 0.912 | 79.78 | 5.51 | 44 | 25 | 3 | 2 |
| 2020 | 12.53 | 0.943 | 96.41 | 5.68 | 53 | 31 | 3 | 2 |
| 2025 | 14.47 | 1.089 | 111.3 | 6.57 | 62 | 36 | 3 | 2 |
| 2030 | 16.58 | 1.058 | 127.5 | 6.39 | 71 | 41 | 3 | 2 |

