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ESTIMATION AND TREND ANALYSIS OF BIOMASS PRODUCTION IN RIVER BASIN IN TAIWAN: 2. CASE IN GAOBING RIVER BASIN

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Key Words **:** Material flow, Southern Taiwan, Gaobing River basin, biomass, agriculture production

ABSTRACT

This study analyzes the variations of the biomass (including crop, forestry, fishery and livestock) production in the Gaobing River basin in the Southern Taiwan to establish the useful information and indicators, which can be considered as the reference for assessing the improvement development. The material production of biomass materials MPB during 1987 to 2001 are computed from the available date and assessed. The results reveal that the contribution of rice planting in the Gaobing River basin has decreased with time in recent years. Accordingly, the contribution of rice product (M_R) in the Gaobing River basin for the whole rice product (M_{RTWN}) in Taiwan also reduces gradually as well. The M_R/M_{RTWN} decreases from 2.52% in 1987 to 1.51% in 2001 with the average value of 1.78%. Furthermore, the MPB in the Gaobing River basin generally increased before 1996, and then decreased in the following two years (1997 and 1998) because of the eruption of foot and mouth disease. On the whole, the MPB with the average value of 1,053,115 tons increases from 854,973 tons (in 1989) to 1,243,260 tons (in 2001). In addition, the variations of the ratio of farm to total populations (P_{Fa}/P_T) and cultivated land area (A_C) are addressed. The P_{Fa}/P_T and A_C range within 24.5-33.0% and 10,880-26,724 ha with the average values of 28% and 15,580 ha, respectively. The biomass industrial gross domestic product per unit biomass weight (GDP_B/MPB) and the ratio of GDP_B to total gross domestic product (GDP) in the Gaobing River basin are also investigated. Here, the measurement of GDP is based on the constant price of 1996. The GDP_B/MPB with the average value of 0.32 US$/kg has the maximum and minimum values of 0.40 and 0.22 US$/kg, respectively. The low value of GDP_B/MPB reflects the low economical efficiency of biomass industry. Moreover, the values of GDP_B/ GDP decrease gradually from 5.6% in 1987 to 2.5% in 2001, with average value of 3.7%, indicating decreasing contribution of biomass industry.

INTRODUCTION

Material flow analysis is essential to the study on industrial ecology [1]. The material flow database of Taiwan from 1986 to 1998 has been established by the previous studies [2-8]. However, the information about various regions in Taiwan still needs to be investigated. It is beneficial to compare and assess the facts and conditions of resources utilization in the various regions [9]. Based on the concepts of input and output material balance, a system can be constructed to evaluate the productivity of industries in order to trace the uses of nature resources [10]. The information is also necessary for promoting the development in Taiwan [11]. As a result, this study aims at the analysis of the variations of biomass (including crop, forestry, fishery and livestock) production in the Gaobing River basin in the Southern Taiwan.

Note that this study only considers the regional productions, while does not include the input and output of the biomass materials, wastes and emissions of the pollutants in the Gaobing River basin. The data about the material flows and annual revenue from the

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governmental statistics are collected for evaluating the material related indictors proposed by WRI *et al.* [12]. In addition, some environmental indicators related to the economic development reported by Ausubel [13] such as population (P) and gross domestic product (GDP) are discussed in this study. The results can be referred for dealing with policy-making affairs, economic efficiency and environmental consideration in the Gaobing River basin. Furthermore, they can also be served as the useful information for assessing the improvement of the development in Taiwan.

METHODOLOGY

The data about biomass (including crop, forestry, fishery and livestock) production during 1987 to 2001 in the Gaobing River basin are collected from the Statistical Abstract and Agricultural Statistical Yearbook, which are published by the county and municipal governments [14-16] and Council of Agriculture of Taiwan [17], respectively. The administration districts (or areas) in the Gaobing River basin include Kaohsiung city, 12 towns (or villages) of Kaohsiung County, Ping Tung City and 9 towns (or villages) of Ping Tung County. The individual data about these districts are collected and summed for the further investigation. The counting of the material flows is based on the well defined functional parameters, which can provide the useful and standardized approach, assuring that the calculations of different kinds of materials are based on the same principles [12,18]. However, some data of some items are not available in some districts. This study adopts the methodology of similarity and proportionality to estimate these unknown items from the known information as follows.

The estimated unknown amount of material j of the specific towns of the county in the Gaobing River basin = total statistical amount of the whole county in the Gaobing River basin × $\sum_{i=1}^{N} R_i / N$ (1)

R_i = the ratio of known amount of material i of the specific towns of the county in the Gaobing River basin to that of the whole county in the Gaobing River basin. N = total number of i. The applicable counties in the Gaobing River basin are Kaohsiung County and Ping Tung County. As illustrations, the estimations of some unknown items are listed as follows.

Case 1. Estimation of flowers, forage and green manure crops:

N = 5, i = the products of rice, common crops, specific crops, vegetable and fruits.

Case 2. Estimation of hairy antlers, cow's milk, honey and royal jelly:

N = 5, i = the yields of beef, pork, lamb, domestic fowls and egg.

Case 3. Estimation of wood, bamboo, forest by-product, afforestation area, tree felling, and aquatic farm:

N = 1, i = the land area.

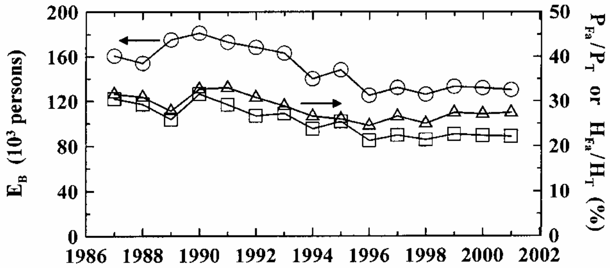

Fig. 1. Time variations of E_B (○), P_{Fa}/P_T (△) and H_{Fa}/H_T (□) in Gaobing River basin. E_B: agricultural employmee P_{Fa}: farm population. P_T: total population. H_{Fa}: farm households. H_T: total households.

Case 4. Estimation of pelagic, inshore, and coastal fishing, sea farming, and inland breed:

N = 1, i = the fishery population.

Case 5. Estimation of biomass industrial GDP (GDP_B):

N = 1, i = agricultural employment (E_B)

Case 6. Estimation of total GDP (GDP):

N = 1, i = population.

In addition, due to the lack of the statistical data of E_B during 1994-2000 in Kaohsiung County, the E_B is estimated by assuming that E_B is proportional to the farm family ratio (H_{Fa}/H_T, ratio of farm to total households). Furthermore, the statistics in the governmental organizations' web sites has also been referred to examine the reliability of data [19-22]. The non-weight units of the data are converted to weight based on the Chinese National Standard of Taiwan (CNS). The calculation of hidden flows is not considered in this study because of the lack such data.

RESULTS AND DISCUSSION

The E_B, ratio of farm to total populations (P_{Fa}/P_T), and ratio of farm to total households (H_{Fa}/H_T) in the Gaobing River basin are shown in Fig. 1. It shows that the E_B decreases gradually with time, especially during 1992-1996 with 25% reduction. The E_B approaches to the stable value of about 135,000 employees after 1996. The P_{Fa}/P_T with the average value of about 28% varies only slightly with time. Moreover, the farm population (P_{Fa}), which decreases 7.5% from 245,051 persons in 1987 to 226,568 persons in 2001, is considered more stable comparing with the E_B (with the reduction of 19% from 1987 to 2001). The variation trend of H_{Fa}/H_T is similar to that of P_{Fa}/P_T. The ratio of average values of P_{Fa}/H_{Fa} to P_T/H_T is about 1.1. Therefore, the persons in the farm households are about 10% greater than those in the total households.

Regarding the cultivated land area (A_C), A_C per farm household (A_C/H_{Fa}) and A_C per agricultural employee (A_C/E_B) are shown in Fig. 2. The value of A_C

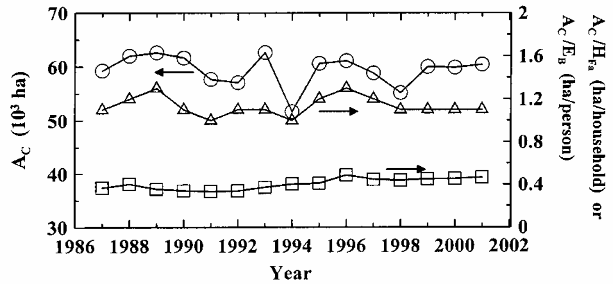

Fig. 2. Time variations of A_C (○), A_C/H_{Fa} (△) and A_C/E_B (□) in Gaobing River basin. A_C: cultivated land area. Other notations: as specified in Fig. 1.

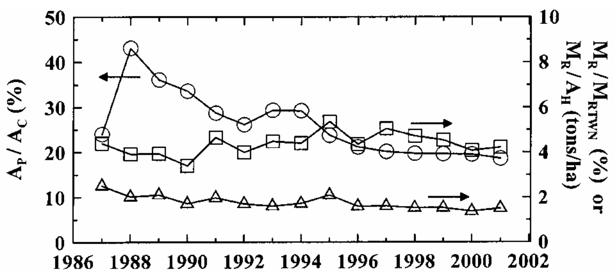

Fig. 3. Time variations of A_p/A_C (○), M_R/M_{RTWN} (△) and M_R/A_H (□) in Gaobing River basin. A_p: planted land area. M_R: regional rice production. M_{RTWN}: whole rice production in Taiwan. A_H: harvested land area. A_C: as specified in Fig. 2.

ranges about 59 (± 3) × 10^3 ha over the period of 1987 to 2001, while the average value of A_C/H_{Fa} is 1.15 ha/household. The maximum value of A_C/H_{Fa} is 1.3 in 1996 due to the significant decrease of the farm households in Kaohsiung County. The value of A_C/E_B is below 0.4 during 1986-1993, and increases slightly from 1994 to 1996 because of the decrease of E_B. The A_C/E_B has a maximum value of 0.487 (in 1996) with the increase of 46% comparing the minimum value of 0.334 (in 1991).

The ratios of planted to cultivated land areas (A_P/A_C), regional to whole Taiwan rice productions (M_R/M_{RTWN}) and the rice product per harvested land area (M_R/A_H) in the Gaobing River basin vary with time as shown in Fig. 3. The percentage of A_P/A_C with the average value of 26.3% has a maximum value of 43.1% (in 1998) and a minimum value of 18.6% (in 2001). It reveals that the proportion of rice planting area becomes lower. This may be because that some crops with high economical value are planted instead of rice planting. The regional rice production (M_R) in the Gaobing River basin shows a significant decrease of 55.7% from 158, 462 tons in 1987 to 88,397 tons in 2001. Correspondingly, the M_R/M_{RTWN} value of 2.52% and 1.51% in 1987 and 2001, respectively, shows a gradual decrease with time. Nevertheless, the M_R/A_H value varies within 3.4-5.4 tons/ha showing a moderate variation. The average value of M_R/A_H of

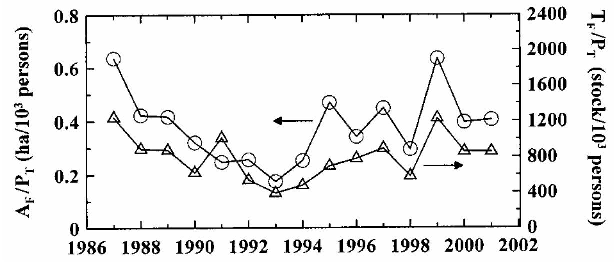

Fig. 4. Time variations of A_F/P_T (○) and T_F/P_T (△) in Gaobing River basin. A_F: reforestation land area. T_F: reforestation trees. P_T: as specified in Fig. 1.

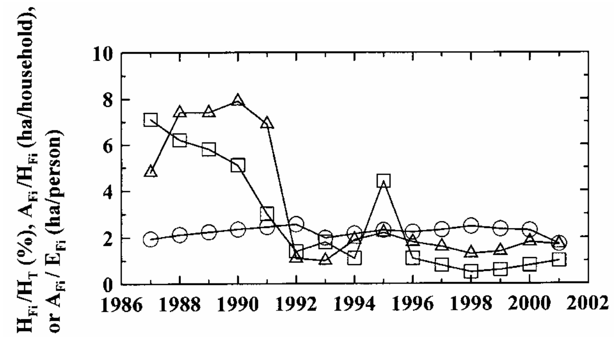

Fig. 5. Time variations of H_{Fi}/H_T (○), A_{Fi}/H_{Fi} (△) and A_{Fi}/E_{Fi} (□) in Gaobing River basin. H_{Fi}: fishermen household. A_{Fi}: aquaculture land area. E_{Fi}: fishery employee. H_T: as specified in Fig. 1.

4.4 tons/ha is greater than that in the Tamsui River basin, showing a higher productivity of rice. A comparison of the results indicate that the cause of reduction of rice production in the Gaobing River basin is mainly due to the decrease of A_P but not of the productivity of rice denoted as M_R/A_H. The time variations of reforestation area per person of total population (A_F/P_T) and reforestation tress per person of total population (T_F/P_T) in the Gaobing River basin are shown in Fig. 4. The value of A_F/P_T initially decreases with time to reach a minimum value of 0.17 ha/10^3persons in 1993. Afterwards, the A_F/P_T increases reaching a maximum value of 0.64 ha/10^3persons in 1999 due to the encouragement of reforestation policies of the government. The variation trend of T_F/P_T is similar to that of A_F/P_T with maximum and minimum values of 1,227 and 391 stocks/10^3persons, respectively. The average value of T_F/A_F is about 2093 stocks/ha during 1986-2001. Furthermore, the recent variations of A_F/P_T and T_F/P_T become stable due to the enhancement of environmental protection consciousness.

The variation of fisherman to total households ratio (H_{Fi}/H_T), aquaculture land area per fisherman household (A_{Fi}/H_{Fi}) and aquaculture land area per person employed in fishery (A_{Fi}/E_{Fi}) are shown in Fig. 5. The value of H_{Fi}/H_T mainly ranges between 2.0-2.5% and decreases in the recent years. Note that the H_{Fi} value decreases from 5,444 households in 2000 to

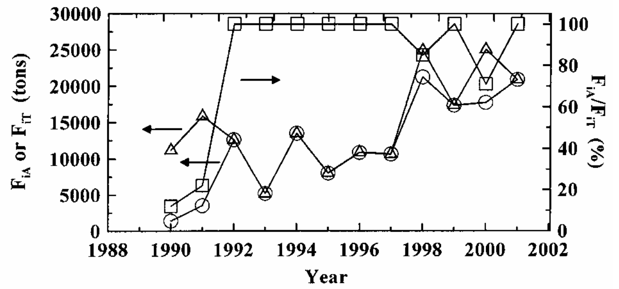

Fig. 6. Time variations of F_{iA} (○), F_{iT} (△) and F_{iA} / F_{iT} (□) in Gaobing River basin. F_{iA}: aquaculture fishery production. F_{iT}: total fishery productions.

4,111 households in 2001 showing an apparent decrease of fisherman households in the Gaobing River basin. Moreover, A_{Fi}/H_{Fi} and A_{Fi}/E_{Fi} have the higher values prior to 1990 while decrease remarkably during 1990-1992 due to the increases of H_{Fi} and E_{Fi} during that period. The values of A_{Fi}/H_{Fi} and A_{Fi}/E_{Fi} after 1992 approach to the stable ranges of 1.3-2.0 ha/household and 0.5-0.6 ha/person, respectively. In addition, the time variations of the ratio of aquaculture fishery production (F_{iA}) to total fishery production (F_{iT}) are shown in Fig. 6. It is obvious that the aquaculture fishery becomes a major portion in the fishery industry from 1992 due to its high economic benefit. The water used in the aquaculture fishery is drawn from the ground water. However, the environment has been seriously damaged resulted from the lack of proper design for the use of ground water. For example, the useful land has decreased in the region of Wu-Fang area in Xin-Yuan village due to the overdrawing of groundwater resulted in a sink of land. The border of coast in Ping Tung County also reduces about 2.9 m and causes the problem of the salinization of well water.

We only analyzed the MPB (material production of biomass), including crop (C), forestry (F), fishery (F_i) and livestock (L) materials, in the Gaobing River basin between 1987 ~ 2001. The items of crops consist of rice, common crop, special crops, vegetable, fruits, flowers, forage and green manure crops. As for the forestry, the items include beef, pork, lamb, domestic fowls, eggs, hairy antlers, cow's milk, honey and royal jelly. The fishery materials contain pelagic, inshore and coastal fishing, sea farming and inland breed. Finally, the items of livestock take into account for wood, bamboo and forest by-products. The productions of pigs (M_{PG}) are about 93,067 tons in 1987 and increase evidently with time until 1996 with an increase of 118% based on the estimation of 112 kg per pig [17] as shown in Fig. 7. Afterwards, the value of M_{PG} begins to decrease due to the eruption of foot and mouth disease in 1997. Note that Taiwan EPA (TAIEPA) also promotes the policies to help pig-raising households to transfer their occupations and processes the drift fence of pig farm to reduce the

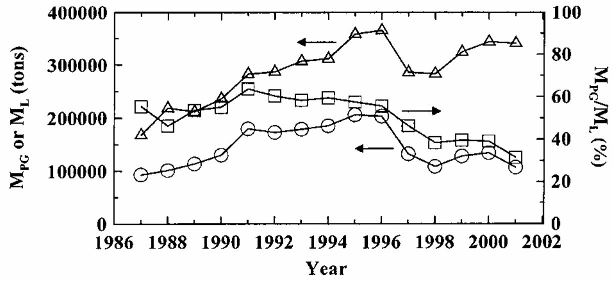

Fig. 7. Time variations of productions of M_{PG} (○) and M_L (△), and M_{PG}/M_L (□) in Gaobing River basin. M_{PG}: weight of pigs production. M_L: weight of livestock production.

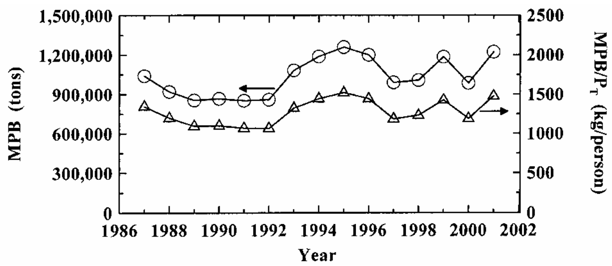

Fig. 8. Time variations of MPB (○) and MPB/P_T (△) in Gaobing River basin. MPB: material production of biomass. P_T: as specified in Fig. 1.

number of pigs according to the law. As a result, it can be found that the weight ratio of production of pigs to livestock (M_{PG}/ M_L) is greater than 50% before 1996 while decreases below 50% from 1997 as depicted in Fig. 7. The results demonstrate the good performance of TAIEPA in executing its policies. The variations of MPB and MPB per person of total population (MPB/P_T) in the Gaobing River basin are shown in Fig. 8. The MPB decreases from 1987 of 1,041,375 tons until 1992 with the reduction of 10%. It then begins to increase gradually during 1993 to 1995. However, the significant decrease of MPB in 1997 is caused by the eruption of foot and mouth disease. This phenomenon indicates that the production of MPB in the Gaobing River basin has tended to increase recently. It shows that the variation trends of MPB may be due to the variation of industrial structure in the Gaobing River basin. Further examination of the effects of variation of industrial structure on the domestic wastewater generation in the Gaobing River basin would be helpful in future study.

The variation of MPB/P_T is similar to that of MPB with maximum and minimum values of 1520 and 1066 kg/person in 1995 and 1992, respectively. Further, the average value of MPB/P_T in the Gaobing

River basin is 1,275 kg/person representing a high production requirement as compared to that (57 kg/person) in Tamsui River basin. The values of biomass industrial gross domestic product (GDP_B) per MPB and the ratio of GDP_B to GDP in the Gaobing

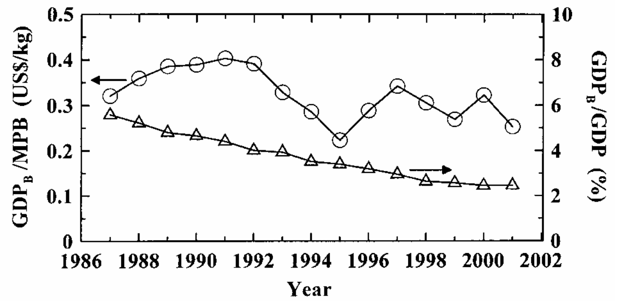

Fig. 9. Time variations of GDP_B/MPB (○) and GDP_B/GDP (△) in Gaobing River basin. GDP: gross domestic product. GDP_B: biomass industrial GDP. MPB: as specified in Fig. 8.

River basin can be calculated based on the exchange rate of 1US$ = 27.46 NT$ in 1996 as illustrated in Fig. 9. Note that the value of MPB/GDP reflects the requirement of biomass production per dollar. Reversely, the value of GDP/MPB displays the economical efficiency of material production. The GDP_B/MPB increases gradually from 0.32 US$/kg in 1987 to a maximum value of 0.40 US$/kg in 1991. The efficiency then decreases obviously to reach a minimum value of 0.22 US$/kg in 1995, and varies within 0.25-0.34 US$/kg during 1996-2001. Furthermore, the contribution of the biomass industry for the GDP in the Gaobing River basin decreases evidently with time according to the decreasing trend of GDP_B/GDP. The value of GDP_B/GDP is 5.6% in 1987 and decreases continuously to 2.5% in 2001. Note that the GDP_B/GDP value becomes stable of about 2.5% in recent years.

CONCLUSIONS

The time variations of biomass production of crop, forestry, fishery and livestock in the Gaobing River basin provide useful information to assess the situation of the biomass industry. From the analysis of this study, the agricultural employees, the ratio of planted to cultivated land areas and the ratio of biomass to total gross domestic products are found to decrease remarkably with time. The results reveal that the importance of biomass industry in the Gaobing River basin gradually decreases due to the changes of the industrial and economic structures. On the other hand, the time variation of the cultivated land area is stable. Also, the aquaculture fishery apparently becomes a major contribution in the recent fishery industry. Moreover, the production of pigs and the ratio of productions of pigs to livestock significantly decrease due to the eruption of mouth and foot disease and the implement of the policies promoted by the government. Therefore, in order to improve development, the government should consider how to utilize the agriculture area and set the adequate directions of agriculture development utilizing the existing biomass resources. Otherwise, the environment would be degraded gradually due to the improper use of the biomass resources such as overdrawing the underground water. Consequently, the transformation of agriculture development in the Gaobing River basin is important and necessary because of less agricultural employees and low biomass industrial gross domestic product, while of the serious environmental problems.

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NOMENCULTURE

Notation Referred to Gaobing River Basin

A	Agriculture
A_C	cultivated land area
A_F	reforestation land area
A_{Fi}	aquaculture land area
A_H	harvested land area
A_P	planted land area
B	biomass including crop, forestry, fishery and livestock
C	crop
E_B	agricultural employees
E_{Fi}	fishery employmee
F	forestry
Fi	fishery
F_{iA}	aquaculture fishery production
F_{iT}	total fishery production
GDP	gross domestic product
GDP_B	biomass industrial GDP
H_{Fa}	farm household
H_{Fi}	fisherman household
H_T	total households
L	livestock
M_L	weight of livestock production
MPB	material production of biomass
M_{PG}	weight of pigs production
M_R	regional rice production
P_{Fa}	farm population
P_T	total population
PG	pig population
T_F	reforestation trees

Notation Referred to Other Regions

M_{RTWN} whole rice production in Taiwan

R_i ratio of known amount of material i of the specific towns of the county in Gaobing River basin to that of the whole county in Gaobing River basin

Other Notations

CNS Chinese National Standard (Taiwan)

TAIEPA Taiwan Environmental Protection Administration

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台灣河流流域生產之生物資源物質計算與趨勢分析 —案例 2: 高屏溪流域

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關鍵詞：物質流、南台灣、高屏溪流域、生物資源、農業產量

摘　　要

本研究探討南台灣高屏溪流域生物資源(包含農林漁牧物質)產量的變化，以整理及建立該流域有用的物質資料及指標，並可以作為未來評估發展改進的參考。根據本研究所分析 1987 到 2001 年的相關數據，可得到生物物質產量(MPB)的變化。從長期趨勢來看，高屏溪流域之稻作面積近年來日漸減少，顯示該流域漸漸不進行稻作生產。故高屏溪流的稻米產量(M_R)，對整個台灣地區的稻作產量(M_{RTWN})的貢獻度也逐漸減小。M_R/M_{RTWN} 的比值從 1987 年的 2.52%減少到 2001 年的 1.51%及其平均值為 1.78%。此外，高屏溪流域的 MPB 值在 1996 年以前通常都是增加的，但是在後續的兩年(1997 和 1998)因為口蹄疫的爆發而明顯減少。整體而言，MPB 值從 1989 年的 854,973 公噸上升到 2001 年的 1,243,260 公噸，其平均值為 1,053,115 公噸。同時相關的農業人口與總人口數之比值(P_{Fa}/P_T)及耕地面積(A_C)的變化也在本研究中加以探討。P_{Fa}/P_T 與 A_C 的數值分別介於 24.5-33.0%和 10,880-26,724 ha，以及其平均值分別為 28%和 15,580 ha。另外對於單位生物物質所產生的生物物質相關的生產毛額(GDP_B/MPB)，及 GPD_B 相對於高屏溪流域的總生產毛額(GDP)之比例亦進行分析和研究 (GDP 計算值之基期年為 1996 年)。GDP_B/MPB 之平均值為 0.32 US$/kg，其最大值為 0.40 US$/kg 及最小值為 0.22 US$/kg。此低 GDP_B/MPB 值反映高屏溪流域其生物物質之低經濟效率。此外，GDP_B/ GDP 亦逐漸從 1987 年的 5.6%降低至 2001 的 2.5%。顯示高屏溪流域之生物物質產業對總產業之貢獻逐年下降。