Population Growth and Environmental Problems in Taiwan (Formosa): A Case-study

by

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INTRODUCTION

Taiwan Island has an area of about 36,000 km², being slightly smaller than Holland. Sixty-nine per cent of the land is occupied by high-mountain forests (altitude > 1,000 m), 25% is agricultural, 2% is residential and industrial, and the remaining 4% is used for various other purposes. The total population today is about 16 millions. The population density in 1974 reached 436 persons/km², which is the highest in the world—as compared with Japan's 296, Holland's 332, and the United States' 23 in the same year. The *per caput* income is about $660 (1975), which is, next to Japan, Singapore, and Hong Kong, the fourth-highest in Asia. In food production Taiwan is generally self-sufficient. Industry and international trade have expanded dramatically since the mid-1960s.

How Taiwan has been able to feed a large population with a moderate material living-standard, in spite of very limited natural resources, is often cited as a model for the developing countries of Asia. It is consequently worth while to study the present situation closely in order to determine how the population growth and rapid industrialization during the last 10 to 15 years have affected the living environment in Taiwan, and to foresee their continuing and long-term implications.

The essential statistical data used in this work [but not cited in the text] are from the following four reference sources unless otherwise indicated: Taiwan Provincial Government publications, '*Fifty-one Years' Summary of Taiwan Statistical Data*' [1945] and '*Twenty-one Years' Statistics of Taiwan Province, 1946–1967*' (in Chinese); Economic Planning Council, Executive Yuan publication, '*Taiwan Statistical Data Book 1975*'; and Teng-Hui Lee's '*Intersectional Capital Flows in the Economic Development of Taiwan 1895–1960*', Cornell University Press [1969].

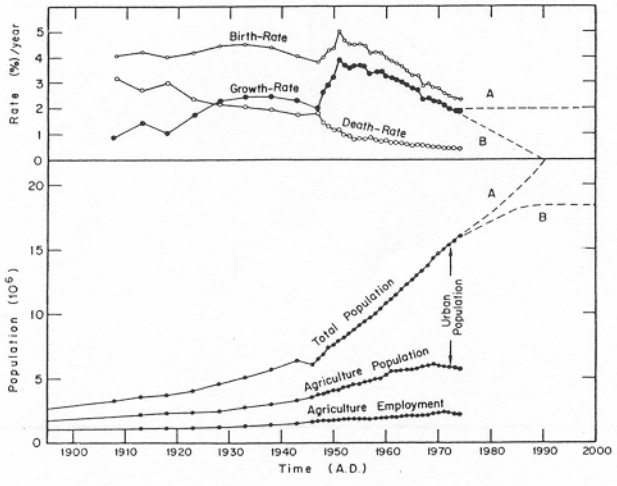

FIG. 1. *The essential population statistics of Taiwan since 1895. The less-crowded data-points always represent five-years averages, whereas the more crowded ones are of yearly data. The broken lines A and B represent two possible future trends.*

POPULATION GROWTH

The population of Taiwan is estimated to have been about 200,000 around A.D. 1650, since when it has increased about 80-fold. According to the more reliable population-statistics since 1895, the population growth-pattern has followed a classical three-stage model (Fig. 1). The first stage (before A.D. 1920) is characterized by both a high annual birth-rate and death-rate (~4% and ~3%, respectively), and the second stage (1920–51) by much the same high birth-rate (4–5%) but a decreasing death-rate (from ~3% down to ~1%). Thus the natural growth-rate * of the population in the second stage increased from 1% to almost 4%, especially in the years immediately following World War II, being most pronounced in

* Natural growth-rate = birth-rate *minus* death-rate; social growth-rate = immigration rate *minus* emigration rate; total population growth-rate = natural growth-rate *plus* social growth-rate.—Ed.

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1946–51. The third stage (1951 to the present) has been marked by an ever-decreasing birth-rate (from ~5% down to ~2.5%) and a decreasing death-rate (from about 1% down to ~0.5%). The natural population growth-rate has decreased from 4% to less than 2% in the last 25 years.

The decrease in the birth-rate since 1951 indicates the general acceptance of birth control measures by society after experiencing the keen population pressures just after World War II. The dramatic decrease in the death-rate after the war testifies to the success of modern medicine in eliminating most epidemic diseases, and it is much to be hoped that the next stage will be a period of low birth-rate and low death-rate, when population growth will eventually fall to zero. If one assumes, optimistically, that the birth-rate will continue to decrease linearly, as it has in the last 25 years, the population-growth will become zero in 1990 (the dotted line B in Fig. 1), and the total population at that time will be about 18 millions. Otherwise, with the present growth-rate (~2%), the population will double every 35 years (the dotted line A in the lower part of Fig. 1).

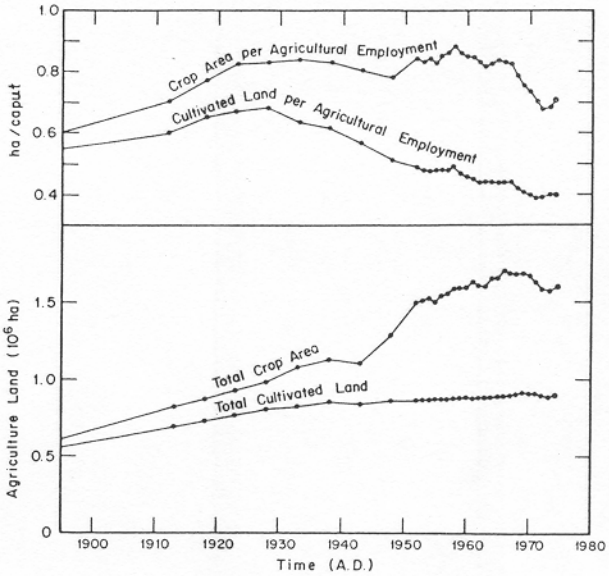

FIG. 2. *The total and* per caput *cultivated land and cropland in Taiwan since 1895. The less-crowded data-points represent five-years averages. The crop area is greater than the area of cultivated land because there may be 2 or even 3 crops in a year.*

AGRICULTURAL POPULATION

The growth-rate of the agricultural population and of agricultural employment have been much lower than that of the total population (Fig. 1): since 1911, the total population has multiplied about 6 times but the agricultural population has multiplied only 3.5 times and the agricultural employment 2 times. In 1911 the agricultural population comprised 63% and the agricultural employment 33% of the total population, but today the percentages are reduced to only about 33% and 14%, respectively. Meanwhile the area of cultivated land increased only 36% from 1911 to 1969; thereafter it even decreased slightly, owing to the expansion of cities and industrial complexes (Fig. 2).

Fortunately, Taiwan is located in a subtropical climatic zone with plenty of rainfall. Where there are good irrigation systems, the agricultural land can be planted and harvested twice (or even three times) a year, given also the proper amount of fertilizers. Therefore the total effective crop-area every year can be far greater than the actual area of cultivated land, as is indicated in Fig. 2. The big jump in the total crop-area per year from 1945 to 1951 corresponds nicely with the sharp increase in population growth-rate in the same period (cf. Fig. 1).

The population pressure is demonstrated with particular clarity in the agricultural sector by the ever-decreasing share of cultivated land for each agricultural labourer since shortly before 1930 (Fig. 2). At the peak time around 1930, each agricultural labourer cultivated, on the average, nearly 0.7 hectare of land in Taiwan, but today this has decreased to barely 0.4 hectare, which is pitifully small when compared with the areas cultivated by individual farmers in other countries (for example in Japan 0.6 hectare for each farm labourer, in West Germany 3.2, in France 5.8, in USSR 6.1, in U.S.A. 48, in Canada 81, etc., according to 1971 United Nations statistics). It is interesting to note that, in Taiwan, the crop area per year for each farm labourer had been fairly constant (0.8 ha/labourer) in the period 1920–65, but thereafter it also started to diminish (Fig. 2). It seems that 0.8 hectare of cropland per year is the minimum requirement for optimal utilization of farm labour in Taiwan; this also means that the agricultural sector can no longer absorb extra farm-labour without sacrificing the productivity of each labourer which has been maintained since the mid-1960s. It is not a coincidence that the government's decision to import large amounts of foreign capital to expand the industrial sector was also taken in the mid-1960s.

FOOD PRODUCTION

In the matter of food production, Taiwan has always been more or less self-sufficient. Taking the main crop—rice—as an example, brown-rice production has almost always been greater than consumption (the only serious exception being for two years around the end of World War II) as shown in Fig. 3. But since 1968 the production of rice has no longer increased in proportion to population growth as before; instead it has fallen slightly, coincidentally with the shortage or irregular supply of fertilizers

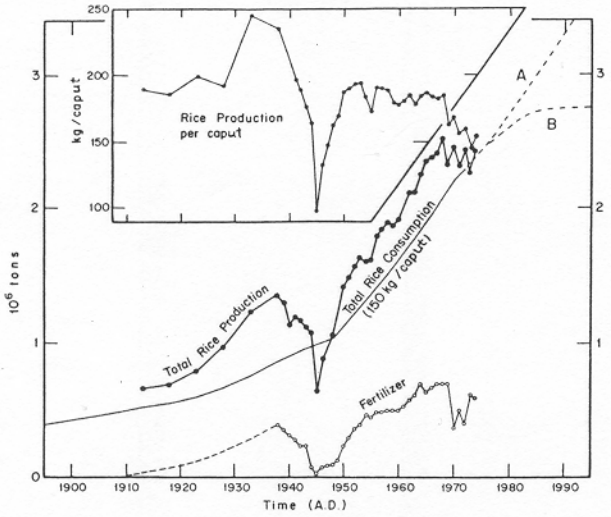

FIG. 3. *The yearly production and the estimated consumption of brown rice in Taiwan, as well as (below) the application of fertilizers to rice paddy each year since 1910. The less-crowded data-points represent five-years averages. The broken lines A and B represent the possible future consumption as estimated from Fig. 1. The 'tons' referred to are metric tonnes.*

(Fig. 3). Besides the improvements in the irrigation system and the introduction of the high-yield rice strains, the productivity of a rice paddy in Taiwan depends heavily on the amount of fertilizer applied, as is shown in Fig. 4 (data from Fig. 3 divided by the annual cropped area of rice). Unlike those for nitrogen fertilizer, the raw materials for potassic and phosphatic fertilizers are almost entirely imported. Moreover, as two-thirds of the commercial energy is also imported into Taiwan nowadays, the cost of producing N-fertilizer became expensive after the energy crisis of 1973. So the labour-intensive crops, such as mushrooms, asparagus, various fruits, etc., produced for export, became an important part of the agricultural economy.

Besides fertilizers, the application rate of various pesticides has increased exponentially since 1950 (National Health Administration (Taiwan) [N.H.A.], 1974). The contamination of rice-paddy soil with various chlorinated hydrocarbons and heavy-metals (Table I) is already widespread (C.C. Li & Li, 1973; C.C. Li *et al.*, 1973; N.H.A., 1974). According to a governmental survey (N.H.A., 1974), the Hg content of brown rice grown in Taiwan ranged between 0.01 and 0.09 ppm in the years 1968 and 1969, but thereafter increased drastically to 0.5–1.5 ppm at the end of 1970. The apparent reason is that, early in 1970, Japan totally banned the use of organomercury pesticide, whereupon Taiwan, unknowingly or knowingly, imported large amounts of 'cheap' organomercury pesticide from Japan. Although organomercury pesticide was banned in Taiwan in late 1972, as late as 1974 about 20% of the mushroom crop examined, which had been grown on rice straws, still contained more than 0.1 ppm mercury, which greatly depressed the foreign demand for exported mushrooms.

Because there is as yet no legislative control in Taiwan of the permissible limit of Hg content in foods, unexportable mushrooms (Hg $>$ 0.1 ppm), as well as unexportable sea-food products (e.g. swordfish and shark with Hg $>$ 0.5 ppm), have been consumed in Taiwan. Organoarsenic pesticides are still widely used by farmers in Taiwan, and in 1972 random sampling of rice from markets showed a high content of arsenic (0.4–3.6 ppm). Indeed, eight samples out of ten exceed by 1 ppm the arsenic tolerance standards of England (Su, 1973). As in other industrial countries, DDT and its derivatives, and BHC, etc., can be detected in vegetables, streams, fish, shell-fish, and indeed practically everywhere on the island (Lo *et al.*, 1973; Sun, 1974).

The coastal plains around the island are already over-saturated with population. The only way to reduce the pressure has been to move some people farther onto the mountain slopes and high-mountain

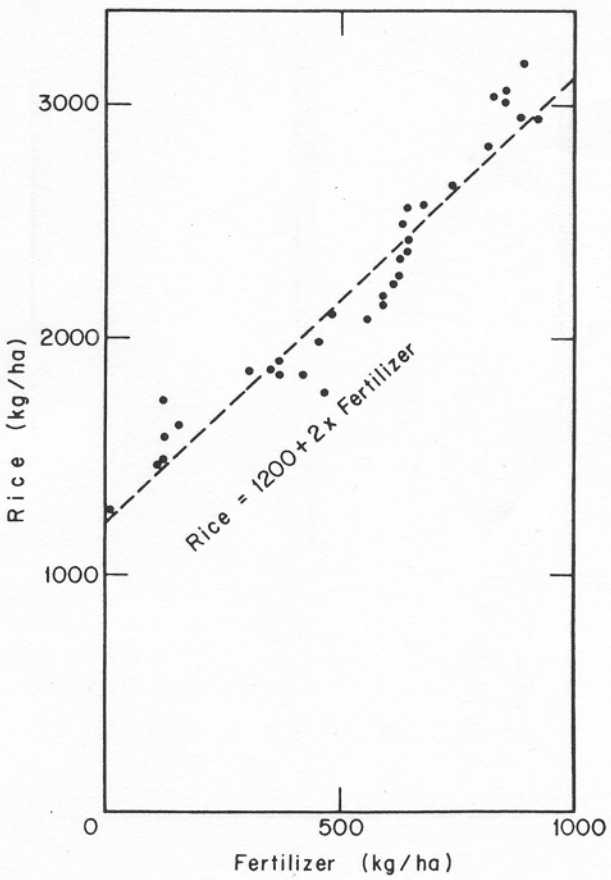

FIG. 4. *The linear relationship between brown-rice production per unit area and fertilizer application per unit area in Taiwan in the period between 1938 and 1969.*

TABLE I

The Average Contents of Mercury (ppm) and Chlorinated Hydrocarbons (ppb) in Rice-paddy Soil Sampled at Various Localities in Taiwan, 1972.

Soil depth (cm)	*Hg (ppm)*	*Lindane (Υ-BHC) (ppb)*	*Heptachlor (ppb)*	*Heptachlor epoxide (ppb)*	*Aldrin (ppb)*	*Dieldrin (ppb)*	*ΣDDT (ppb)*
0–13	0.22	11.8	1.2	2.1	11.3	17.8	85.3
13–26	0.15	4.7	0.5	2.1	1.6	11.7	20.5
26–38	0.10	3.8	0.4	0.6	1.1	7.4	3.7
Average 95% decomposition time (years)*		6 (3–10)	3.5 (3~5)	—	3 (1–6)	8 (5–25)	10 (4–30)

* Numbers in parenthesis are the possible range of 95% decomposition time.

areas, and to exploit the natural resources there. The big problem encountered there is the rapid erosion of soil and concomitant landslides in the areas where the forests have been cleared. The average erosion rate of the high-mountain area is about 1.3 g/cm² year by natural causes alone (Y.H. Li, 1976), which is probably the highest known value in the world. Very careful and systematic planning is badly needed if flooding in the plains and silting of reservoirs are to be avoided.

URBANIZATION AND INDUSTRIALIZATION

Since 1911 the urban population has multiplied about eightfold in Taiwan. In 1911 the urban population accounted for only 37% of the total population, but today it is about 67% (Fig. 1). An even more striking fact is that the number of cities with a population greater than 25,000 was only two in 1900, accounting for only about 4% of the total population, whereas by 1970 the number had increased to 38, accounting for 38% of the total population. This population is concentrated in an area constituting about 2% of the island. Therefore the average population-density of the cities is now more than 7,200 persons/km² whereas in the U.S.A. it is about 1,500/km². Migration into the cities is still continuing. For example, in 1972 (Table II) the annual social growth-rate * of the cities was about 1.9% (an average of 1.73% and 2.07% for male and female, respectively). Therefore, in addition to a 2% natural growth-rate, the total growth-rate of the cities is about 3.9%, which, if continued, would lead to a doubling of the population of the cities every 18 years. On the other hand, all urban and rural townships showed a negative social growth-rate, especially in the aboriginal townships (high mountain areas). The negative social growth-rate for females there is larger than the natural growth-rate; thus the total number of females in the aboriginal townships has been decreasing, which causes some marriage problems in the mountain regions. The mobility of the female is always greater than that of the male everywhere in Taiwan (Table II), as the 'unwanted' farm labourer is usually female. Meanwhile, most of the assembly-line-oriented new industries prefer female labourers, because they will work for lower wages.

The concentration of population in cities causes not only many new social problems (which are beyond the scope of this paper) but also many environmental

* *See* footnote on page 171.

TABLE II

Movement of Population Inside Taiwan, 1972.

Cities and Townships	*Immigration rate %*		*Emigration rate %*		*Social growth-rate %†*	
	M	*F*	*M*	*F*	*M*	*F*
Five big Cities*	13.36	14.49	12.20	12.68	+1.16	+1.80
County Cities	8.79	9.38	7.06	7.31	+1.73	+2.07
Urban Townships	5.12	5.66	5.65	6.25	−0.52	−0.59
Rural Townships	4.11	4.64	5.20	6.05	−1.09	−1.41
Aboriginal Townships	2.29	2.58	3.87	5.20	−1.58	−2.62

* Taipei, Kaohsiung, Taichung, Tainan, Keelung.

† Social growth-rate = immigration rate *minus* emigration rate.

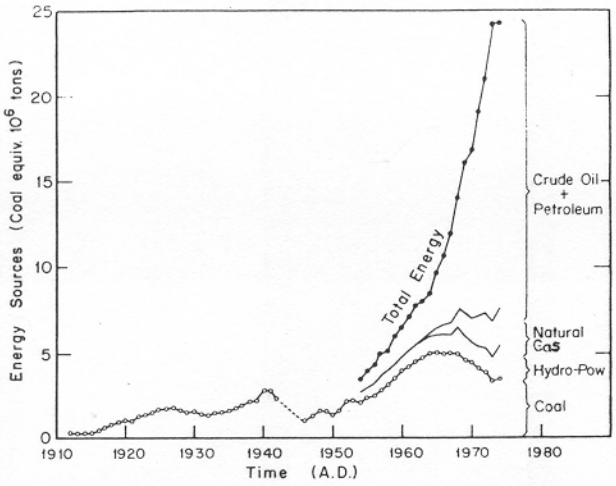

FIG. 5. *Consumption of energy from various sources each year in Taiwan. Note the declining trend of coal production since 1968. The 'tons' referred to are metric tonnes.*

ones. In traditional agricultural practice in Taiwan, human excreta have always been recycled back to the land. But the concentration of the population in the cities causes its collection and transportation for farm use to be much more expensive. It is not surprising that the farmer prefers the cheaper, 'cleaner', and more effective, chemical fertilizers. As a consequence the city sewage, as well as industrial waste, is directly discharged into the near-by river system without any prior treatment. The solid wastes of cities and industries are also often piled up along the river-bank or sea-shore. Most of the downstream rivers on the west coast of Taiwan are already badly polluted by excessive organic materials from cities and industries (e.g. sugar mills, paper mills, food processing factories, etc.), and some are contaminated by poisonous chemicals and heavy-metals from various industries (Taipei Planning Committee of Sanitary Sewers [T.P.C.O.S.S.], 1972; Shen & Wang, 1973; Hung *et al.*, 1973, 1974, 1975).

The polluted rivers, in turn, pollute the coastal marine and estuary environs. The coastal shellfish culture-beds south-west of Taiwan have been wiped out during the last 10 years by pollutants from the cities of Kaohsiung and Tainan (two of the largest in south-west Taiwan). The shellfish culture-beds in the middle section of the west coast have been damaged every spring (when the rainy season begins) for the last seven years. The damage is primarily caused by the low oxygen-content of the river water bearing excessive organic materials and heavy-metals (Hung *et al.*, 1975). This trend will surely destroy most of the shellfish cultures and the near-shore fisheries of Taiwan in the near future.

The rapid industrial growth in Taiwan is demonstrated by the exponential increase of the total energy consumption since the mid-1960s (Fig. 5). Hydro-power, natural gas, and most of the coal, are produced internally, while crude oil and petroleum are mostly imported from Saudi Arabia and Kuwait. In 1974 about 70% of the energy depended on imports. Of the total electric-power supply, hydro-power accounted for only 23% while the rest was obtained from thermo-power plants. However, there is now the promise of increased domestic supply from the new-found oil-fields in the off-shore area south-west of Taiwan.

As the sulphur contents of the coal (0.6–3%) and crude oil (~3.6%) used in Taiwan are high, air pollution problems are also becoming more serious—for example acid rain, high concentrations of suspended particles, SO_2 and CO in the air. etc. (Taiwan Provincial Research Institute of Environmental Sanitation, 1972; Chuang, 1973; Lü *et al.*, 1973). The death-rate from lung cancer has increased drastically since 1955 for both males and females (Fig. 6); moreover it is now four times as high in urban cities as in rural areas (Lu *et al.*, 1974). Changes in smoking habits have not been the main cause of the increase of lung cancer in Taiwan, because most female adults in Taiwan are non-smokers (Lu *et al.*, 1974).

In order to decrease the dependence on imported oil, Taiwan is building two nuclear power-plants on the northern coast of the island, and is planning several more on both the northern and southern coasts. Thermal pollution alone from these will probably destroy the coral colonies which also, unfortunately, exist only on the northern and southern coasts of the island—not to mention disposal and leakage problems of radioactive wastes.

As both natural resources and the consumer market within the island are very limited, international trade is an essential part of the economy today. The dependence on trade can be estimated by the ratio of total trade values (import values plus export values) of the gross national product (hereafter referred to as TT/GNP) as shown in Fig. 7. The TT/GHP ratio increased from 20% in 1950 to 40% in 1968, and reaches more than 90% today. For comparison, the TT/GNP ratio of Japan is about 22%, of England

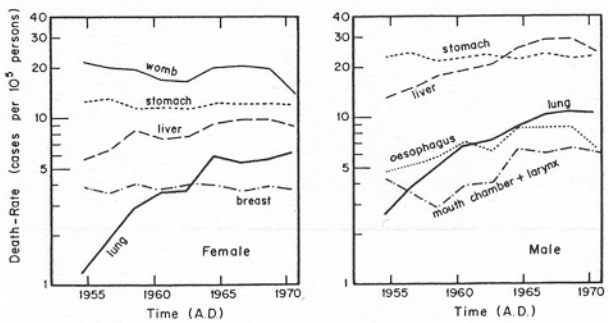

FIG. 6. *Death-rates due to various malignant cancers in Taiwan. (Data taken from Lu* et al., *1974.)*

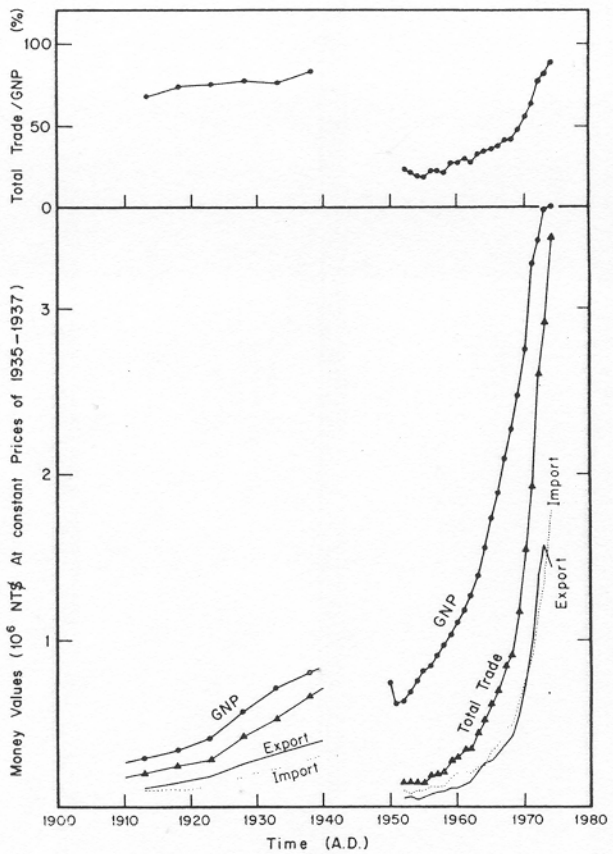

FIG. 7. *The increasing trend of Taiwan's total trade, GNP, and the total trade/GNP ratio, since 1950.* See *text for explanation of data before World War II.*

37%, of Western European countries 20–40%, and of the U.S.A. 10% (1972 United Nations statistics).

During the period 1895 to 1945, Taiwan was under the control of Japan; therefore trade was limited to Japan only. Taiwan exported mainly agricultural products and some raw materials, and imported consumer products, fertilizers, and capital for the modernization of the agricultural and transportation systems. Exports always largely exceeded imports, contributing greatly to the formation of Japanese capital. Since the 1950s, Taiwan's main trade partners have been Japan (on average 40% of the total imports; 15% of total exports between 1970 and 1974) and the U.S.A. (25% of imports; 39% of exports between 1970 and 1974). The composition of import items has been mainly raw materials for agriculture and industry (~60%), and capital goods (35±5%) since 1965. Before 1952, the main export items were agricultural products (95%); but in 1974 agricultural products accounted for only 15%, the remainder being industrial products (mainly textiles, assembled electronic items, household items, etc.). The deficit of trade after World War II has been partly balanced by U.S. economic aid (grants and loans, etc.).

Foreign capital (again mainly Japan and the U.S.A.) has been attracted to Taiwan by many factors, including (1) the relatively cheap and stable labour-market, (2) skilled and hard-working labourers, (3) tax incentives, and (4) no stringent pollution control legislation, etc. The last item is very important in terms of the environment: many factories which cannot operate legally in their own countries have moved to Taiwan. Most factories, to save production costs, operate without even rudimentary pollution control. In a sense, Taiwan becomes an importer of pollution as well as of more desirable commodities.

In order to strengthen the industrial basis of Taiwan, the government has initiated 9 or 10 large projects, including the installation of nuclear power-plants, steel and shipyard industries, oil refineries, the construction of a new international airport and seaport, a north–south super-highway, reservoirs, and modernization and extension of the present railway system. The impact of these projects on the future environment of the island is still a big unknown.

Fig. 8 shows the relationships among the *per caput* energy consumption, population density, and energy consumption per unit area, for various countries in 1972. (Note: the area of each country includes only FAO-defined agricultural areas.) If the energy consumption per unit area roughly corresponds to the pollution potential of the area, then the pollution potential of Taiwan is already as high as that of the industrialized European countries. (Note: area-wise, in huge countries such as the United States, Canada, Australia, etc., the local pollution potential could be as high as in European countries, as is indeed the case for the east coast of the United States.) As Taiwan does not have adequate legislation on pollution control, the actual pollution levels are probably equal to or higher than those of many European countries,

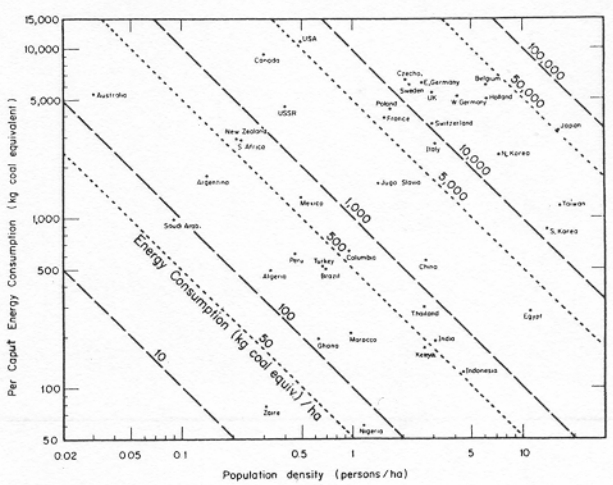

FIG. 8. *The relationships among* per caput *energy consumption, population density, and energy consumption per unit area (or pollution potential), for different countries in 1972.*

although the rapid industrialization started in Taiwan only 15 years ago.

CONCLUSIONS

Taiwan has been successful in feeding her ever-growing human population by introducing modern agricultural technology, increasing the crop-areas to optimal upper limits, and importing a large amount of foreign capital to expand industry and trade. But her economy has become increasingly dependent on the outside world, as is also the case for Japan and the western European countries. They depend very much on the exportable food and consumer market of North America, OPEC's oil, and raw materials from all over the world, for maintaining their high material living-standards, while tending to degrade their own local as well as the world-wide environment.

One cannot help but wonder what will happen to industrial civilization when the food that is exportable from North America becomes zero (Brown, 1975)—as seems practically bound to happen through increase of population in North America itself and/or stagnation of food production caused by shortages of energy, etc. At that time, people will probably no longer care about pesticides, heavy-metals, and various artificial chemicals in their food, nor about the 'abstract' concept of quality of life, but simply live for survival's sake.

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SUMMARY

Taiwan has the highest population density in the world today. The population growth-rate has been decreasing linearly since 1951, but the present growth-rate of 2% is still much too high to lessen the population pressure. With the area of agricultural land severly limited, the agricultural sector of Taiwan can no longer absorb extra farm labourers without sacrificing the productivity of each farm labourer.

In order to feed the growing population, the high productivity of a rice paddy has been maintained by applying ever-increasing amounts of chemical fertilizers and pesticides, which in turn cause many pollution problems. Moreover the rapid growth of industries, which are mainly financed by outside capital, causes the expansion and congestion of the cities along with all sorts of pollution problems (air pollution of cities, water pollution of rivers, harbours, coastal waters, etc.)

The heavy dependence on imported energy (70% of the total energy consumption) and on trade with Japan and the United States, puts Taiwan in a vulnerable position with regard to fluctuations in the world economy. The ever-increasing population density, and the demands of a higher *per caput* consumption on the limited natural resources, risk leading to economic inadequacy and ecological degradation. Such a situation could endanger our industrial civilization more widely.

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