Development Perspectives of Irrigated Agriculture in Indonesia

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INTRODUCTION

Indonesia's economic development is depended in large part on changes in the agricultural sector, particularly in the irrigated agriculture. The importance of irrigation development and management has been demonstrated by its significant contribution to food crop production and its significant share of public expenditures. Despite favorable policy support on irrigation in the past, in recent years, however, there has been a considerable slowdown in the rate of growth in rice yields.

This paper explores the complex issues related to irrigation management in Indonesia from the view point of development perspective. First it highlights irrigation development during the colonial and post-colonial period, followed by discussions on the trend of land and water resources utilization, and its consequence on production. Finally it draws some implications on food security and poverty reduction in Indonesia.

IRRIGATED AGRICULTURE DURING COLONIAL PERIOD

Irrigation was developed during the period of Hindu Rulers around the end of the first millennium in Java and Bali. This was considered major revolution in rice culture, which then gave rise to important social change in terms of division of labor and accumulation of wealth. Because of the increasing population pressure traditional methods of rice culture did not produce sufficient food. Irrigated agricultural practices were expanded to meet the increasing demand for rice. However, as the capacity of rice fields increased through irrigation, so did the population (Leander1992).This is particularly true for Java as reported by Boeke (1966), that the increasing production of rice was followed by the increasing population which caused the farmers in irrigated areas in Java remain poor.

One of the cultural inheritances on irrigation is the Balinese Subak system. Following Geertz (1963) the Subak is more than just "irrigation society" although its central role is on water management. The Subak is in fact an agricultural planning unit, an autonomous legal corporation and a religious community. It is quite different from the large irrigation systems in continental Asia which exhibit "despotism." Water management of the Subak systems and

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other traditional systems in Java are local and intensely democratic in nature. The advantages of these traditional systems, in which the canal layout generally classified as bifurcating system water, are divided in fixed proportion (Horst1998). Water allocation and its control system are open to society and the system is designed to enable equal access of water as an important principle of justice.

Contrary to the traditional systems, modern irrigation systems were introduced by the colonial rulers in the middle of nineteenth century as a response to inadequacy of food and most likely as a trial and error for larger scale irrigation in the downstream areas of river basins. The hierarchical canal layout is mostly adopted in modern irrigation projects. The water is distributed to large blocks and subdivided into smaller units.

The main feature of this modern system is the establishment of "a yearly cultural plan." It consists of two major components namely the cropping system plan and water distribution plan (Gruyter1933; Graadt van Roggen1935). The first refers to the arrangement of the crops within an irrigation system in a given year or in a given planting season and the second refers to allocation and scheduling of water supply to meet crops demand for water in a given cropping system plan.

The use of control structures such as "romijn" gates and geographically unequal positions of irrigation units may render unequal access to water (Horst 1998). Inherent in the design of modern irrigation system is the need for bureaucratic control of water to manage conflicts in water distribution during a planting season. The studies of irrigation management during the colonial period were focused on improving irrigation performance to support the cultural plan.

Most of the irrigation systems were run-of-the river type diversion systems with two major constraints during the beginning of the rainy seasons namely low water flow and limited availability of labor for land preparation. One of the major challenges was to develop water delivery scheduling in such a way so that the time for the peak demand for water matched with the time of the peak supply of water. The institution to regulate water distribution and scheduling of water delivery in pre-determined sections of irrigation system was established in 1933 by the name "golongan system"(Gruyter 1933). The development of this institution was supported by earlier studies such as that of Paerels and Eysvogel (1926) on crop-irrigation requirement and by van Maanen (1931) on the optimum size of irrigation unit.

The amount of water required by the irrigation systems in central Java varied between 0.25 liter/second/ha and 0.35 liter/second/ha assuming that all irrigated areas in an irrigation system were planted with secondary crops. Although there is a fixed number of sections of "golongan" in an irrigation system, in practice, there is a flexibility in terms of timing of water delivery depending on the level of water in the canal and availability of labor for land preparation. Generally, water was scheduled with differential time interval of two weeks from the first to the subsequent sections of a "golongan."

The appropriate section of a golongan is a tertiary unit with the maximum size of 100 ha (van der Giessen 1946). By this arrangement it is possible to split the total area irrigated in a village into several sections of golongan so that labor supply for land preparation can be appropriately scheduled. Ideally, the sections of the golongan system should be rotated every year, the last section scheduled in a year should be the first to be planted in the following year. In reality, however, such an arrangement is not always workable (Van der Giessen1946).

Another relevant issue of water management that emerged during the colonial period was water allocation among crops. For this purpose, there are several studies worthwhile to be discussed. Based on the study of Paerels and Eysvogel on the so-called normal supply there was a need to specify the relative irrigation requirement of major crops. There were three major crops identified namely: Paddy, secondary crops which comprise of soybean, corn, peanut, and other upland crops planted on irrigated rice field, and sugarcane as an export commodity. The ratio of irrigation requirements (RIR) between the crops varies from place to place depending on the factors such as topography, groundwater surface, rainfall, and the growing stages of crops.

For practical reasons, however, Van der Ploeg (1936) introduced the use of normative RIR that is 4:1.5:1 for paddy, sugarcane, and secondary crops, respectively. The normative RIR has been used particularly in the irrigated area planted to sugarcane and the secondary crops in addition to rice. The concept of normal supply to irrigate secondary crops is called "Pasten."

The institutional development of water management system at the community level was reviewed by Happe (1936), and Witzenburg (1936). One of the controversial issues was centered around whether irrigation organization should be based on a village-bound system or irrigation unit- bound system as in the case of Balinese Subak system. In Java "Ulu ulu" is an institution responsible for water management at the village level. As reported by Clason (1936) even though a so-called distributor "Ulu ulu" i.e., an Ulu ulu system organized around a tertiary unit was considered more advantageous as compared to "village Ulu ulu system," but this newly introduced Ulu ulu system was not widely accepted by the farmer community.

Basic to the development of water management is the development of physical infrastructure or hardware component. Historically, there were three stages of hardware technological development in Java. The first stage is the development of irrigation systems in the hilly areas where relatively simple hydraulic structures were used. Many of the systems developed by the local community belong to this category. The rules for water delivery are supply driven, continuous flow with relatively minimum need for water control. The second stage is the development of large-scale irrigation systems in the downstream area of river basins with the primary emphasize on the main delivery system. During this stage the principles of water allocation were tested and the results from experiments were used as feedback for the design criteria of canals. During the third stage, further refinement of water distribution and control system took place through further development of physical infrastructures such as field reservoirs, tertiary and quaternary canals. The concept of the Golongan system and Pasten were developed where information on crops planted and scheduling were taken into consideration.

Irrigated agriculture has been the subject of trial and error for centuries; one of the important features of irrigated rice culture is its capacity to absorb a large amount of labor without affecting its production capacity. As emphasized by Geertz and others it was the successful adaptation of wet rice to increasingly labor-intensive cultivation methods that permitted the increase in rural population that have occurred in Java. During the period of heavy irrigation investment between 1880 and 1930 population of Java leapt from 19.5 million to 41.7 million.

There were several reasons for the heavy emphasis on irrigation investment during the first three decades of the twentieth century. In 1901, the Queen Wilhelmina, in addressing the parliament of Netherlands drew attention on the declining state of the native welfare of Java. There were three policy instruments proposed in implementing the " ethical policies" as the key to improve the welfare of the natives namely irrigation, education, and trans-migration. There were disagreements among professionals, however, on the role of irrigation to improve the welfare of the natives. The proponents of irrigation development felt that the major constraint in improving the level of rice production was the shortage of irrigation. Moreover, improved irrigation meant higher yields of non-rice crops, improved rivers, roads and bridges, and better drinking and bathing facilities for human beings and animals (Booth 1971).

Skeptics of the development of irrigation of whom Boeke was one, point to the fact that 25 years of heavy investment on irrigation had not raised yields per hectare of rice in Java nor had it led to any marked improvement in the standard of food consumption per capita. The rapid increase of population of Java was one of the important reasons for the low level of welfare. In addition, the absence of other components of modern production technology such as high yielding varieties and fertilizers was the likely reason for insignificant increase in rice production. The increase of production during the period of 25 years was mainly due to the expansion of harvested rice area.

There was another important fact reported by Booth (1971). For the latter part of the1930s, data on rice yield were available for Bali and Lombok. Although there were no irrigation investments made by the government, the rice yield in this region was more than 50 percent higher compared with those of Java for the same period. The possible reason was that the water management of the indigenous irrigation system in Bali had been brought to a considerable degree of sophistication over centuries and the higher yield figures testify its performance.

IRRIGATED AGRICULTURE DURING THE POST-COLONIAL PERIOD

During the post-colonial period the changes in rice cultivation practices occurred quite rapidly, particularly induced by the advent of green revolution and the increasing demand for food. Irrigation systems inherited from the colonial period are important endowments to meet one of the national development objectives, that is self-sufficiency in rice production. Most of the irrigation systems constructed during the colonial period were good in the quality of construction. Through the rehabilitation program that occurred during early seventies to early eighties and also due to incentives such as fertilizer subsidy, rice yields were increased significantly during this period. Boeke (1966) and other "pessimists" were apparently right that irrigation investment during the colonial period had little positive impact on the welfare of the local community. On the other hand, the proponents of the development of irrigation systems were very right from a long-term perspective—that because of this important irrigation investment, Indonesia was able to achieve self-sufficiency in rice production in 1984.

The principles of water allocation based on Pasten as the decision-making criteria is still used particularly in an irrigation system with diversified crops. The Golongan system is continually planned to optimize the use of labor and water for land preparation at the beginning of the planting season.

Other cultivation techniques in rice-based farming systems exercised by the farmer community in response to variability of water availability are well known *sorjan* and *gogorancah* . At the early stages of development sorjan used to be practiced in the downstream portion of an irrigation system in the northern coastal area of Java. It is used either to solve the problem of floods or drought. It is the land-shaping management comprising furrow and bed. In the case of risk reduction of floods as practiced in the north-eastern tip of West Java, paddy is planted at the top of the furrow and the lower part of the bed is used for fish ponds. On the contrary, paddy is planted at the lower part of the bed and secondary crops at the upper part as in the case of the irrigation systems in the coastal area of Central Java, to reduce the risk of water scarcity that occurs in the downstream area of the irrigation system. Now, sorjan is being practiced extensively in the tidal-swamp reclaimed area of Sumatra and Kalimantan.

Gogorancah is another response to the variability of water status in the field. In the areas of high risk of flood, the upland cultivation technique is practiced even before the onset of rainy season. The field is planted with paddy by direct seeding without soil puddling. During the peak of the rainfall the plant is quite high so that when the flood occurs its effect will not be serious. This technique is practiced in the flood-prone areas or in the irrigated area with relatively late commencement of irrigation, and also in the rainfed paddy fields. Introduction of this practice in Lombok Island, eastern part of Indonesia, during the early seventies had increased rice production and reduced poverty.

As the demand for rice continually increased in response to population and better incomes, the effort to increase paddy cropping intensity became essential. In the irrigated areas with a year round flow of water, three crops a year are attainable by adoption of short duration high yielding varieties and by application of "Walik jerami" technique where at the end of the cropping season soil moisture is high enough to enable the next planting without adequate land preparation as it is usually done during the rainy season. Planting three paddy crops a year, however, is only practiced in limited irrigation systems as it is considered sensitive to pests and diseases. In Java, there are about three hundred thousand ha of irrigated land planted with three paddy crops a year.

TRENDS IN LAND AND WATER RESOURCES

Land and water resources are not well distributed throughout the country due to population density and resource-endowment differences. The present total population of Indonesia is more than 200 million, of which 60 percent is living in Java although it only comprises about 7 percent of the total land area of two million square kilometers. Water resources management has played an important role in economic development, in terms of both production and public expenditures: by 1980, irrigation investment accounted for more than half of the public expenditure, with publicly funded irrigation accounting for 85 percent of the irrigated area and 75 percent of the country's rice production (Rosegrant et al. 1987).

The program is often cited as a success; with the spread of irrigation, Indonesia's rice production has achieved and maintained a level of self-sufficiency during the period from 1984 until early 1990s.

The country's continued economic development will require additional development of its water resources. Even though Indonesia is blessed with abundant water resources, some parts—especially the crowded island of Java—have begun to feel the effects of water scarcity as well as land scarcity. There is a tendency of Java dwindling as a rice producer of the country. The share of Java as a rice producer had declined from 60 percent in the early 1980s to 52 percent in the 1990s. There has been continuous reduction of irrigated lands in Java. For example, between the period 1980–1990 there was a conversion of about 170,000 ha of wetland rice to other uses (Pasandaran 1996). The area converted in the early 1990s was about 23,000 ha per year with about 38 percent of the total converted land in East Java and an additional 32 percent in West Java. Substantial portion of the converted area comes from highly productive technical irrigation systems. In East Java, for example, about 30 percent of 38,000 ha converted to other uses from 1989 to 1992, was originally technically irrigated area.

Two patterns of conversion can be discerned: a) contiguous blocks of area surrounding development concentrations (such as in the northern coastal area of West Java), around development of settlements, industries, and roads; or b) more fragmented blocks of area, converted as a result of degradation of rice-lands and declining income opportunities (or as dependency has shifted to other rice-fields).

In contrast with Java there has been a continuous increase of irrigated lands in outer islands although the net increase is not sufficient to compensate for losses of production in Java because of the differences in productivity and cropping intensity. The productivity of the new irrigated area outside Java is very low because these new irrigation systems face production constrains such as inadequate water management and production technologies. Inadequate capacity of water management is also the likely reason for low cropping intensity in addition to low opportunity cost of this endeavor compared to other farming development alternatives.

Agricultural land conversion is difficult to avoid, but policy intervention is needed because the problem is not only related to the losses in irrigation investment but also to food security. In the long run, conversion may have a significant impact on degradation of water resources which in turn will increase the social cost.

As a consequence of continuous conversion of irrigated land and increase in population the size of the landholding is decreasing. In Central Java, for example, the average size of the landholding declined from 0.39 ha in 1994 to 0.35 ha in 1998 (CASER 2000). There are regulations regarding conversion of land which are essentially prohibitive to convert the status of technically irrigated land into other uses, but in practice there are no effective measures to enforce these regulations. Because of the increasing demand for nonagricultural lands the local governments tend to endorse the conversion for the sake of regional development.

If the above mentioned permissive policy implementation on land conversion continues to occur in the future without any compensating policy measures such as investment on new irrigated land and improvement in crop productivity, the gap between rice production and consumption will continue to increase, and consequently, the increasing burden on import of rice.

Even though in the past the policy priority was on rice self–sufficiency, to be achieved by promoting irrigation, the current policy objectives are broader. It includes promoting diversification of agricultural commodities. Law 12 (1992) on crop cultivation system provided farmers the freedom to plant crops of their own choice, with the presumed effect of inducing crop diversification in irrigated areas. The practice of crop diversification, however, is generally effective in the area that has a long experience in water management support system such as the Pekalen sampean irrigation systems, East Java.

PRODUCTION AND POLICY SUPPORT

As rice has been considered a main food commodity, greater attention was paid to rice production. Significant growth in the past was achieved due to the government policies including investment in irrigation and research, extension programs for new technologies and inputs, and favorable input and output pricing policies. The irrigation investment program has included not only the construction of a new system, but also large investments in the rehabilitation of the existing systems, and in the development of tertiary distribution systems within existing irrigation schemes.

The combination of research, investment, and pricing policies has led to rapid growth in the use of modern varieties and fertilizer with impressive gains in rice yield per hectare. Data on area harvested, production and productivity from 1970 to 2000 is presented in table 1 and the share of area harvested and yield to the growth of production is presented in table 2. The share of area harvested fluctuates with the maximum contribution of 2.10 percent in Java during the period 1980-1985. The share of productivity/yield has shown a declining trend during the period 1975-2000 while in the outer island it shows a trend of increasing share of productivity in the first five year period and then followed by the declining share of productivity.

The area harvested in the outer island showed an increasing trend from the period between 1970 and 1995 and the period from 1995 to 2000 showed a declining trend in the share of area harvested. Table 3 indicates that the cropping intensities of irrigation rive both in Java and outer islands are already high. During the period from 1982 to 1999 the cropping intensity of irrigated rice in Java only slightly increased from 1.71 to 1.79 and in outer island from 1.43 to 1.70.

The slowdown in the rate of yield growth is due to near completion of the spread of modern varieties and intensified production programs, declining marginal productivity of fertilizers, a less favorable price environment and, reduction in irrigation investment and the completion of new and rehabilitated areas.

The possibility to increase rice production in the near future however is constrained by the lack of new innovation in production technology and lack of pace to complete the on-going activities in rehabilitation and land development.

IMPLICATIONS FOR FOOD SECURITY AND PRO-POOR INTERVENTION STRATEGIES

In the future Indonesia will enter an era of severe land and water shortage for food production. The population will continue to grow while the growth rate of food production shows sign of stagnation.

The fundamental reason for low production growth is the leveling-off of productivity factors i.e., cropping intensity and yield, and also area irrigated. Further analysis reveals that the yields have been stagnant for a decade. The average yields of paddy have remained at a level of 4.5 ton/ha. For the important crops such as maize, yields have been stagnant at the level of 2.2 tons/ha since 1989, while soybeans averaged 1.1-1.2 tons/ha. If Indonesia has to meet her own demand for food and feed, given the present level of productivity, cropping intensity and area irrigated, an additional 30 billion cubic meter of water has to be made available for irrigation in the year 2010 (Pasandaran and Sugiharto 1999). The challenge is to identify available potential land and water resources suitable to meet the above mentioned demand and analyze whether they are feasible to be developed in a given period of time.

If such resources are available, further challenge is to identify investment strategies which reduce poverty and provide maximum benefits for the poor people. The proposed actions worth considering are the following:

- Identify the characteristics of the land and water resources, which can be developed to improve the welfare of the poor people.
- Identify the possibility of development of small-scale irrigation systems in order to enable the development of irrigation systems in a relatively shorter period of time.
- Develop investment approach, which enable the poor farmers participate in the design and process of construction and management of irrigation.
- Develop agribusiness model including micro-finance schemes that meet the need of the poor people.

Table 1. Percentage change of harvested area, production and productivity of paddy (wetland + dryland), 1970-2000.

Year	Java			Outside Java			Indonesia		
	Harvested area	Production	Productivity	Harvested area	Production	Productivity	Harvested area	Production	Productivity
1970-1975	1.58	3.42	1.81	1.33	3.96	2.60	1.47	3.63	2.13
1975-1980	0.53	6.06	5.50	1.93	5.45	3.45	1.17	5.83	4.60
1980-1985	2.10	5.63	3.45	1.71	5.68	3.91	1.92	5.65	3.66
1985-1990	0.44	2.33	1.88	2.02	3.98	1.93	1.18	2.97	1.76
1990-1995	0.22	0.71	0.49	3.23	3.70	0.46	1.72	1.94	0.22
1995-2000	0.96	0.70	-0.26	-0.34	0.67	1.01	0.29	0.69	0.27

Table 2. Harvested area, production and productivity of paddy (wetland + dryland) 1970-2000.

Year	*Java*			*Outside Java*			*Indonesia*		
	Harvested area (ha)	Production ton	Productivity ku/ha	Harvested area (ha)	Production ton	Productivity ku/ha	Harvested area (ha)	Production ton	Productivity ku/ha
1970	4,302,202	11,601,576	26.97	3,596,048	7,092,073	19.72	7,898,250	18,693,649	23.67
1971	4,416,135	12,414,686	28.11	3,908,187	8,069,001	20.65	8,324,322	20,483,687	24.25
1972	4,331,759	11,924,848	27.53	3,565,879	7,469,085	20.95	7,897,638	19,393,933	24.56
1973	4,567,136	13,041,042	28.55	3,836,468	8,449,536	22.02	8,403,604	21,490,578	25.57
1974	4,730,002	13,884,085	29.35	3,778,596	8,591,988	22.74	8,508,598	22,476,073	26.42
1975	4,653,270	13,726,424	29.50	3,841,826	8,613,031	22.42	8,495,096	22,339,455	26.3
1976	4,465,569	14,062,052	31.49	3,903,190	9,238,887	23.67	8,368,759	23,300,939	27.84
1977	4,377,719	13,726,163	31.35	3,981,849	9,620,969	24.16	8,359,568	23,347,132	27.93
1978	4,750,299	15,597,877	32.84	4,178,870	10,173,693	24.35	8,929,169	25,771,570	28.86
1979	4,628,496	15,702,591	33.93	4,175,068	10,580,072	25.34	8,803,564	26,282,663	29.85
1980	4,777,139	18,420,506	38.56	4,227,926	11,231,399	26.56	9,005,065	29,651,905	32.93
1981	5,045,975	20,530,310	40.69	4,335,864	12,243,866	28.24	9,381,839	32,774,176	34.93
1982	4,749,073	20,855,038	43.91	4,239,382	12,728,639	30.02	8,988,455	33,583,677	37.36
1983	4,779,155	21,628,297	45.26	4,383,314	13,674,809	31.20	9,162,469	35,303,106	38.53
1984	5,211,599	23,700,326	45.48	4,551,981	14,436,120	31.71	9,763,580	38,136,446	39.06
1985	5,301,407	24,225,280	45.70	4,600,886	14,807,665	32.18	9,902,293	39,032,945	39.42
1986	5,330,560	24,458,814	45.88	4,657,893	15,267,947	32.78	9,988,453	39,726,761	39.77
1987	5,185,138	24,543,526	47.33	4,737,456	15,534,669	32.79	9,922,594	40,078,195	40.39
1988	5,207,779	25,088,279	48.17	4,932,376	16,587,891	33.63	10,140,155	41,676,170	41.1
1989	5,448,547	27,011,257	49.58	5,082,660	17,714,325	34.85	10,531,207	44,725,582	42.47
1990	5,418,824	27,177,422	50.15	5,083,533	18,001,329	35.41	10,502,357	45,178,751	43.02
1991	5,183,947	26,392,552	50.91	5,097,572	18,295,695	35.89	10,281,519	44,688,247	43.46
1992	5,552,565	28,292,421	50.95	5,550,752	19,947,588	35.94	11,103,317	48,240,009	43.45
1993	5,514,744	28,296,673	51.31	5,498,032	19,884,414	36.17	11,012,776	48,181,087	43.75
1994	5,176,237	26,545,565	51.28	5,557,593	20,095,959	36.16	10,733,830	46,641,524	43.45
1995	5,479,396	18,504,453	33.77	5,959,368	31,239,687	52.42	11,438,764	49,744,140	43.49
1996	5,488,947	28,414,056	51.77	6,080,782	22,687,450	37.31	11,569,729	51,101,506	44.17
1997	5,380,976	27,878,934	51.81	5,759,618	21,498,120	37.33	11,140,594	49,377,054	44.32
1998	5,752,012	27,717,293	48.19	5,978,313	21,519,399	36.00	11,730,325	49,236,692	41.97
1999	5,766,614	18,967,074	32.89	6,196,590	31,899,313	51.48	11,963,204	50,866,387	42.52
2000	5,748,247	29,160,286	50.73	5,860,034	22,319,126	38.09	11,608,281	51,479,412	44.09

Table 3. Irrigated cropping intensity of paddy in Indonesia 1982 –1999.

Year	Java			Outside Java		
	Area	Planted area	Crop intensity	Area	Planted area	Crop intensity
1982	2,516,213	4,298,838	1.71	n.a	n.a	n.a
1983	2,494,841	4,300,253	1.72	n.a	n.a	n.a
1984	2,501,258	4,366,307	1.75	1,657,118	2,699,395	1.63
1985	2,482,376	4,364,357	1.76	1,671,236	2,687,726	1.61
1986	2,479,270	4,385,672	1.77	1,713,711	2,704,604	1.58
1987	2,187,854	3,851,976	1.76	1,513,245	2,477,518	1.64
1988	2,523,154	4,441,464	1.76	1,792,192	2,890,296	1.61
1989	2,534,504	4,509,664	1.78	1,852,941	2,996,524	1.62
1990	2,535,665	4,504,367	1.78	1,912,073	3,093,103	1.62
1991	2,546,123	4,476,199	1.76	1,886,044	3,114,281	1.65
1992	2,572,463	4,572,504	1.78	n.a	n.a	n.a
1993	2,585,701	4,607,613	1.78	2,012,037	3,391,309	1.69
1994	2,564,617	4,535,414	1.77	2,017,043	3,360,807	1.67
1995	2,561,693	4,564,604	1.78	2,126,045	3,585,184	1.69
1996	2,566,209	4,572,248	1.78	2,193,944	3,688,311	1.68
1997	2,550,076	4,520,076	1.77	2,220,564	3,693,447	1.66
1998	2,536,503	4,548,992	1.79	2,247,949	3,796,923	1.69
1999	2,604,782	4,671,475	1.79	2,427,689	4,117,583	1.70

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