Environmental and Economic Impact of Fish cum Rice and Poultry Production Integration System

O. J. Olapade[1*], T. M. Foday[1], M. D. Kpundeh[1], M. Sellu[1], M. Bashiru[2], R. R. Momoh[3], P. D. Musa[4], P. M. P. Mornya[4], S. G. Melvin[5] and S. B. Mattia[6]

[1]Department of Aquaculture and Fisheries Management
School of Natural Resources Management, Njala University,
Njala, Sierra Leone

[2]Department of Agricultural Economics,
School of Agriculture, Njala University,
Njala, Sierra Leone

[3]Department of Extension and Rural Sociology
School of Agriculture, Njala University, Njala,
Sierra Leone

[4]Department of Horticulture
School of Natural Resources Management
Njala University, Njala, Sierra Leone

[5]Crop Science Department
School of Agriculture
Njala University, Njala, Sierra Leone

[6]Department of Forestry
School of Natural Resources Management
Njala University, Njala, Sierra Leone

**Corresponding author's email: fem66 [AT] hotmail.com*

ABSTRACT---- ***The economic viability and environmental friendliness of integrating fish with rice and poultry was evaluated in a fish pond (520m^2); a paddy platform (8 x 25m^2) sown with 1.00kg NERICA 19; a poultry house (3.5 x 11m in dimension) and a maggoty. Integrated pond was stocked at 1.923 fish per m^2 (25g mean weight) while 400 day-old broilers were housed. Water quality parameters determined were within recommended range for the culture of tropical fish species and statistically non-significant ($p < 0.05$). The synergy gave positive Net Present Value NPV of*** **Le 18,520,661.51 (US$4,161.95*)*** ***in the third year; a benefit-cost ratio of 1.23 and two year payback. Sensitivity calculated was 23.6% an indication of the sensitivity of the investment to survival rate. Integrating fish with rice and poultry is environment friendly, and economically viable with potential to create employment, augment income and improve the living standard of sub Saharan poor population.***

Keywords--- Profitability, Integrated Aquaculture, Water Quality

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1. INTRODUCTION

The world population is increasing and has been projected to reach 9.2 billion in year 2050 [1]. This along with increasing urbanization and rising per capita incomes has tripled the worldconsumption between year 1961 and 2001, from 28 to 96.3 million ton [2]. Fish plays a vital role in feeding the world's population and contributing significantly to the dietary protein intake of hundreds of millions of the populace of the world. On a global scale, production from capture fisheries has leveled off and most of the main fishing areas have reached their maximum potential. Fish supplies from capture fisheries according to FAO will, therefore, not be able to meet the growing global demand for aquatic food [3]. With decreasing fish catch across West Africa in contrast with growing populations and increasing demand for food, aquaculture can play a role in helping to increase fish production. Integrated fish farming which is a combination of aquaculture with agriculture is presumed to fit into the picture of fixing hunger in Sub Saharan Africa. Integrated fish farming offers great efficiency in resource utilization and effective farm wastes management. The rising cost of protein-rich fish food and chemical fertilizers as well as the general concern for energy conservation has created awareness in the utilization of rice and other crop fields and livestock wastes for fish culture [4]. Fish culture in combination with agriculture or livestock is a unique and lucrative venture and provides a higher farm income, makes available a cheap source of protein for the rural poor, increases productivity on small land-holdings and increases the supply of feeds for the farm livestock [4]. Thus this system provides better production, provides more employment and improves socio-economic status of farmers and betterment of rural economy. The culture of fish with rice and poultry production which is one of the popular integrated systems allows for the simultaneous production of fish, rice and poultry in a safe way. Wastes generated from the poultry are used as fertilizer for rice and fish pond or directly as feed in form of maggots for the fish. Research has shown that the performance of rice is significantly improved by the rice – fish integration compared to the monoculture of rice [5]. The main objective of integrated aquaculture is to establish a highly flexible system with low external inputs and various outputs all year round.The aim of this present study investigates the economic viability and environmental friendliness of integrating fish with rice and poultry production in an adaptive research farm.

2. MATERIALS AND METHODS

2.1 Description of study area

The research was conducted at Njala University Fish Farm in Moyamba District, Southern Province, Sierra Leone (Figure 1). Sierra Leone is located on the west coast of Africa, between the 7th and 10th parallels north of the equator. The country is bordered by Guinea to the north and northeast, Liberia to the south and southeast, and the Atlantic Ocean to the west. The country has total area of 71,740km2 (27,699sq mi) divided into a land area of 71,620km2 (27,653sq mi). The country has four distinct geographical regions; coastal Guinean mangroves, the wooded hill country, an upland plateau, and the eastern mountain. Eastern Sierra Leone is an interior region of large plateaus interspersed with high mountains, where mount Bintumani rises to 1,948 meters (6,391 ft) [6]. The climate of Njala is mainly tropical and has distinct dry and rainy seasons. Daily mean temperature ranges from $21^{0C}$to 23^{0C} for the greater part of the dry season. The vegetation consists of farm bush, grassland and inland valley swamps.

Figure 1: Map of Sierra Leone showing location of Njala University in Moyamba

2.2 Experimental design

The research was carried out for a period of six months (June – November, 2014). The experimental unit consists of an integrated pond of 520m^2 surface area partitioned into 520m^{2}for fish culture and a centralized paddy platform of 200m^2 for rice cultivation; a poultry house measuring 3.5m x 11m designed to house 400 broilers from day old chicks to table size (reared for 2½ months); A separate pen made of wood and corrugated iron sheets netted with chicken wire mesh was constructed for maggot production (Plate 1).

Plate 1(a,b,c): Fish cum rice and poultry integrated unit set up

2.3 Cultural practices

Lowland NERICCA 19 rice (1.00kg) was nursed for transplanting into the rice paddy at a spacing of 20cm inter rows and 5cm intra rows. The rice paddy was fertilized with organic manure at recommended rate (100 - 300kg fresh manure/ha/day) [7]. This was done twice in a month to avoid the problem of overloading that could lead to water chemical imbalance. Water in the integrated pond was kept low at paddy platform level to prevent the young seedlings from logging by simply lowering the stand pipe at the outlet. Weed was manually removed twice a month (rouging).

2.4 Fish culture

Clarias gariepinus juveniles mean weight 25g was obtained from Magbosie village flood plains and was stocked at a density of 2fish/m^2. Because the fish were obtained from the wild they were initially acclimated for three days without food so as to adjust them to taking imported expanded pellets (45 per cent crude protein). The fish were fed at 5 per cent body weight and feeding was adjusted every month to attune to weight gain. Feeding was supplemented with maggots generated from the poultry manure every one week. Extruded sinking pellets were made locally to reduce the high cost of imported diet which would make it impossible for local farmers to adopt the innovation. The culture period lasted six months.

2.5 Poultry production

400 day old chicks were bought from Pajah hatchery situated at Lumley in Freetown. The chicks were brooded for three weeks indoor using kerosene stoves and coal pots as sources of heat. The heating apparatus were gradually withdrawn as the birds grew feathers and the navel healed. They were vaccinated with Marek`s vaccine at point of collection and also vaccinated against Gumboro and Newcastle diseases while brooding lasts. The vaccination was carried out in the second, third and fifth weeks of their lives. Prophylactic drugs were administered every three days to

forestall the occurrence of diseases outbreak especially bacteria outbreak. Feed and water was given to the birds' ad-libitum. Hanging water troughs adjusted to the reach of the birds were used for the first one month and half but as the bird grew and demand for water increased, five liters plastic bowls were used. The bowls were covered with guards to prevent the birds from defecating in the water and drowning in it. Starter feed used for raising the birds was obtained from Pajah farm but the finisher was compounded in the Department of Aquaculture and Fisheries Management using locally available ingredients (Table 1).

Table 1: Finisher feed composition

Ingredients	**Percentage composition in 100kg**
Concentrate	25
Corn (yellow)	40
Palm Kernel Cake (PKC)	5
Rice bran	22
Oyster	1
Fishmeal	5
Vitamin premix	1.5
Salt	0.5

2.6 Maggot Production

The wastes generated in the poultry house were divided and bagged in polyethylene with the second portion poured into plastic bowls as shown in the plate 1. The wastes were thereafter wetted with water and layered with handful of rice bran for ease of maggot production. The mixture was then left in the open, so that the blow flies could have an easy access. Big brown colored larvae of the blow flies, which are rich in protein, were produced in sufficient quantities after seven days. These were sieved, weighed and poured into the pond for consumption by the fishes. Digested wastes left after maggots were removed and are used as fertilizer for the rice paddy and also for pond productivity.

2.7 Water Quality Assessment

Physico-chemical parameters measured bi-weekly included: Dissolved oxygen, water temperature, *p*H, water hardness, water alkalinity, ammonia, nitrate, BOD and nitrite. These parameters were determined using Jenway analytical probes and Pondlab multi-parameter kits. Water samples were collected at three different points - Point A (water inlet point); Point B (mid-pond close to the paddy platform) and Point C (outlet point). Three samples were collected in cleaned 600ml water bottles per sampling point. The water samples were fixed with 1% concentrated HNO_3 and preserved in the refrigerator at 4^oC prior to analysis in the laboratory.

2.8 Statistical Analysis

Water parameters measured were analyzed using measure of central tendency, one-way analysis of variance (ANOVA) at P=0.05 and mean separation was done using the least significant difference (LSD).

2.9 Economic analysis

Economic viability and performance of the investment was determined through the estimation of production costs, gross revenues, cash flow, and sensitivity of the project, gross merging and benefit – cost ratio using the formulae below.

Incremental benefit = Revenue – Costs
Discounted costs = Discount factor (15%) multiplied by Costs
Discounted revenue = Discount factor (15%) multiplied by Revenue
Net Present Value at 15% = Discounted revenue – Discounted costs
Discounted factor at 15% was calculated as follows
Year 1 = 1 ÷ (1 + 15%)
Year 2 = 1 ÷ (1 + 15%)
Year 3 = 1 ÷ (1 + 15%)

Sensitivity analysis of the project was estimated as = $\frac{\text{Total NPV (3 years) x 100}}{\text{Total Discounted Costs (3 years)}}$

Net profit = (Gross revenue – Total operating costs)
Gross profit margin = (Gross profit) ÷ (Gross revenue)
Payback period = (Total capital cost) ÷ (Net profit)
Benefit – Cost Ratio = Discounted Revenue ÷ Discounted Costs

3. RESULTS

3.1 Physico-chemical Parameters

Results of the physico-chemical parameters measured in the adaptive research pond water are presented in table 1. The values measured throughout the period of the research were within the recommended range for the culture of tropical fish species and were statistically non – significant (P>0.05). Nitrate – Nitrogen and Ammonia/Ammonium (NH_3/NH_4) not detected in the ambient water of the adaptive research pond.

3.2 Economic performance of the Adaptive Research Unit

The results of the variables determined as a measure of the economic viability of the adaptive research units are presented in tables 2, 3 and 4. Table 2 presents the budget/cost and revenue of the research in the first production cycle of the year while table 3 presents the breakdown of expenditures and income of the proposed three years payback period. The cash flow analysis of the adaptive research units is presented in table 4.

The Net Present Value of the project was Le 18,520,661.51 (US$4,161.95**)** while the benefit/cost ratio calculated as Discounted revenue/Discounted costs = 1.23. The assumption that a project is feasible when NPV is positive and benefit/cost ratio is greater than 1 held for this projection.

3.3 Sensitivity Analysis

This a measure for testing risk in investment feasibility especially the influence of unstable prices of inputs on costs of project. For this project the sensitivity was:

NPV at 15% discount rate = Le 18,520,661.51

Total Costs Present Values (CPV) at 15% discount rate = Le 78,481,356.49

$$\text{Sensitivity} = \frac{18{,}520{,}661.51 \times 100}{78{,}481{,}356.49} = 23.6\%$$

This analysis assumed that costs of this project were sensitive to price fluctuations and therefore the investment needs to be properly managed.

4. DISCUSSION

Sustainability of any aquaculture venture especially for enhanced food security and socio-economic development of the target population is the challenge of the new millennium. With the right environment and best management practices (BMPs) the envisaged expectations of the integrated investment could be achieved.

4.1 Water quality

The water quality parameters determined for this study were within the limits recommended by [8][9] and supported both the culture of tropical fish species and the cultivation of rice. The parameters were not statistically significant (P<0.05) although there were variations within the system. It is well known that variations exist between the different environmental compartments in aquatic ecosystems especially with regard to physical, chemical and biological characteristics.

The *p*H of the study area that was initially below the recommended limit of 6.5 – 8.5 [10] was corrected by applying lime ($CaCO_3$). The low acidity of the pond water could be attributed to the fact that the soil of the study area was acidic. Mean dissolved oxygen range of 4.60 ± 0.40 to 7.00 ± 0.12mgL^{-1} recorded is ideal for the culture of C. *gariepinus* and other tropical fish species since it exceeds the 4.00mgL^{-1} critical limit for most tropical bony fishes. Photosynthesis by phytoplankton is the primary source of dissolved Oxygen in aquatic ecosystem [11]. Foraging fish in integrated plots consumed organic matter thereby reducing the requirement for dissolved oxygen [12]. Besides, fish perturbation of the soil can result in aeration of soil and water would have been responsible for the higher dissolved oxygen level (mean values 7.0±0.12) observed in the research plot. Temperature readings ranged from 26.7 ± 0.31 to 30.00 ± 0.15: Nitrate – nitrogen and Ammonia – ammonium was not detected in the pond water throughout the experimental period. The results suggested that the organic loading of the pond was within the water carrying capacity. The mean general hardness and alkalinity of the study which is buffered by the back flushing of River Taia were low with values of 53.4 mgL^{-1} and 35.6mgL^{-1} respectively.

4.2 Economic Performance of the ARP

The Net Present Value (NPV) and the benefit/cost ratio calculated for the business above follows the assumption that a project is feasible when NPV is positive and benefit/cost ratio is greater than 1. However, sensitivity analysis assumed that cost of this project was highly sensitive to price fluctuations and therefore the investment needs to be properly managed. The calculated NPV value was much higher than zero (Le 18,520,661.51; US$ 4,161.95) indicating that the investment is potentially highly profitable, provided the assumptions on which the estimates were based on are fairly accurate. The payback period of two years obtained in this study was within the three years benchmark set for the investment sustainability. The short production cycle (6 months) for catfish as compared to other species such as salmon culture with production cycle of more than a year favours a short payback period [13]. Most investors find projects with short payback periods more economically attractive, especially in markets that are lacking credit facilities. Aquaculture business which takes 5 or more years to payback the cost of investment is considered to be unprofitable [14]. Hence this could serve as an encouragement to investors who normally would prefer a short term investment as a measure of reducing risk. Risk is time related in the sense that the longer it takes for an investment to recoup its cost, the greater the risk of failure. The findings of this study also showed that like many business investments, integrated aquaculture is also a highly capital-intensive business. The average total cost of Le 25,696,392.00 (US$5,774.50) was expended in the first production cycle of the first year and gross revenue of Le 15,146,000 (US$ 3,403.6) was realized.

A positive operating profit indicates that all-integrated fish farming is profitable to operate in the short-term [15]. In this study, Le 12,772,128 (US$ 2,870.14) was expended as variable costs which differed slightly from the fixed costs. This was in consonance with the study conducted by Rosina in Ghana (2010), who reported that majority of the start-up cost goes into the fixed cost. High level of investment capital needed as start-up in an aquaculture business usually stems from the high level of the fixed costs [16]. Steps taken to reduce the operational costs in the form of availability of inputs such as fingerlings and rice seeds at reduced or subsidized cost is in conformity with what was reported by [17]. A study conducted by Engle and Neira revealed that the costs of production among others are dependent on the type of culture techniques used and the costs of inputs employed in the production process [14]. Ability to produce at a least - cost price is determined largely by the species, location as well as feed [18]. Feed is an essential commodity needed in aquaculture operations and the efficiency with which it is utilized for growth depends on its quality and its utilization. In Sierra Leone, availability of good quality fish feed is a major constraint faced by many fish farm operators. Maggots in whatever form derived from the adaptive research cannot completely substitute for rich high quality protein fish feed. The use of termites and non-nutritious feed such as rice bran result in stunted growth of the cultured fish species while importation of extruded fish feed will on the hand exacerbate the cost of production. Thus to obtain better growth of fishes, good quality feed with a high feed conversion efficiency is an option. Attendant to the problem of fish feed is the non-availability of good fish breed in Sierra Leone. Most species used for research are either imported or sourced from the wild. Fish species with fast growth potential that attain market size in preferred time are the *sine quanon*. Good quality fingerlings too are needed to maximize production so as to increase profitability. Profitability is the principal goal of all business ventures. Without profit, the business will not survive in the long-run. Consequently measuring current and past profitability and projecting future profitability is very important [18]. The profitability of the integrated innovation is fairly sensitive to the quality of the fingerlings stocked, because the seed was got from the wild which contributed to the high mortality rate and stunted growth thereby reducing the weight at harvest, with concomitant low revenue. The linkages identified by [16] are very crucial to this study because it clearly shows that the survival rate determines the quantity produced at the end of the production period. Increasing mortality rates leads to low survival rate and thus lower yields. Higher yields coupled with good prices are needed to increase revenue and thus profitability.

4.3 Conclusion

Fresh water aquaculture shows exceptional promise in the integration with other related fields. Integration of rice with fish and poultry as seen in this research is a feasible, profitable and sustainable investment opportunity especially for average African rural farmers who believe that quicker returns are better business. The potential of integrated aquaculture as a source of food, revenue and employment for citizens of developing countries cannot be over emphasized and this potential appears to have been barely scratched. The payback of costs of production could better be shortened by increasing the scale of production since one or two of the factors of production could be held constant. However, to achieve better and quicker returns especially in a country like Sierra Leone, availability of key inputs such as genetically proven fish species, good quality fish feed used as supplementation to maggots and poultry birds are imperative. Sourcing fish seeds from the wild will lead to stunted growth and bad returns and procuring them from overseas will increase the cost of production with attendant longer payback period. From the findings of this study it is evident that importing day-old chicks to Sierra Leone to be resold to farmers exacerbate the cost of production unnecessarily therefore it is advisable for government or other non-governmental organizations with bias to agriculture to intervene with regards to setting up hatchery to breed day-old chicks locally. Njala University for the first time in the history of the country has intervened in the area of genetically proven C. *gariepinus* fingerling and juveniles production locally. Genetically and phenotypically sound brood stocks were pulled together from the adaptive research plot with Deutch Clarias bought in Lagos, Nigeria. This was made possible through the grant provided by CORAF/WECARD. A hatchery has been set up and two trials were carried out with more than 80% success. It is great also to note that Njala University has procured extruding machines from China for the Department of Aquaculture and Fisheries Management for the production of high quality floating pellets locally. It is believed that these efforts will help reduce operating costs with attendant increase in revenue and thus make the integrated innovation in Sierra Leone sustainable and highly profitable.

Table 2: Physico-chemical parameters of the Adaptive Research Pond (ARP)

Month	pH	GH (mg/L)	Alkalinity (mg/L)	NO_3-N	NH_3/NH_4	DO (mg/L)	Temp. (^{0} C)	BOD (mg/L)
June	6.1±0.03[a]	53.4±0[b]	35.6±0[a]	ND	ND	5.2±0.17[a]	29.5±0.56[a]	4.4±0.4[a]
July	6.7±0.46[a]	53.4±0[a]	35.6±0[a]	ND	ND	5.4±0.33[a]	26.7±0.31[a]	4.4±0.4[a]
August	7.2±0.06[a]	53.4±0[ab]	35.6±0[a]	ND	ND	4.6±0.4[a]	30.0±0.15[a]	4.5±0.06[a]
September	7.1±0.1[a]	53.4±0[ab]	35.6±0[a]	ND	ND	5.1±0.2[a]	28.2±1.19[a]	4.6±0.01[a]
October	7.1±0.12[a]	53.4±0[ab]	35.6±0[a]	ND	ND	7.0±0.12[a]	29.13±0.76[ab]	3.7±0.49[a]
November	7.2±0[a]	53.4±0[a]	35.6±0[a]	ND	ND	5.3±0.2[a]	27.4±1.07[a]	4.0±0.58[a]

*Means with the same superscripts within a row are not statistically significant

Table 3: Budget – Costs and Revenues of Adaptive Research Units

1st Year of Operation (1st production cycle)	
Fixed Capital Expenditure	
Construction of poultry house	8,343,250
Construction of maggoty unit	70,000.00
Excavation of pond	2,856,234
Purchase of farm equipment	1,654,780
Operating Expenses	
I. Stock	
400 broilers at Le 6,850/day old chick	2,740,000
1000 fingerlings at Le 1000/fish	1000,000
II. Labour	
Farm hand and harvesters	3,500,000
III. Feed	
a. Fish feed	2,389,000
b. Poultry feed	3,109,000
c. Vaccines and antibiotics	1,562,000
d. Chemical lime and disinfectants	50,000,00
IV. Others	
a. Charcoal (5 bags at Le 12,000/bag)	60,000.00
b. Kerosene (10 gallons at Le 22,500/gallon)	225,000.00
c. Growth boasters (4 sachets at Le 13,782/sachet)	55,128.00
Summary of Costs	
a. Fixed Capital	12,924,264.00
b. Operating Expenses	12,772,128.00
Total	25,696,392.00
Revenue	
400 broiler birds (9.3% mortality) at Le 25,000 per bird	9,070,000.00
1000 table fish (less 40% mortality& adjustment of weight @ Le 10,000/kg fish)	6,000,000.00
Harvested rice (25kg)	76,000.00

Table 4: Financial plan of the investment (3 years payback period)

ANALYSIS OF COSTS	YEAR 1 (Three production cycles)			YEAR 2 (Three production cycles)			YEAR 3 (Three production cycles)		
	A.	**B**	**C.**	**A.**	**B.**	**C.**	**A.**	**B.**	**C.**
I. CASH EXPENDITURE									
FIXED CAPITAL EXPENDITURE									
Construction of poultry house	8,343,250								
Construction of maggotry unit	70,000								
Construction of paddy pond	2,856,234								
Purchase of farm equipment	1,654,780								
OPERATING EXPENSES									
II. Stock									
400 broilers at Le 6850/day old $1.59	2,740,000	2,740,000	2,740,000	2,740,000	2,740,000	2,740,000	2,740,000	2,740,000	2,740,000
1,000 fingerlings at Le 1000 $0.233	1,000,000	-	700,000	700,000	-	700,000	700,000	-	700,000
1.00kg Nerica 19 rice	20,000	-	-	-	-	-	-	-	-
III. Labour									
Farm hand and harvesters	3,500,000	-	-	3,500,000	-	-	3,500,000	-	-
IV. Feed									
Feed for fish	2,389,000	-	2,389,000	2,389,000	-	2,389,000	2,389,000	-	2,389,000
Poultry feed	3,109,000	3,109,000	3,109,000	3,109,000	3,109,000	3,109,000	3,109,000	3,109,000	3,109,000
Antibiotics & vaccines (fish and poultry)	1,562,000	400,000	400,000	1,562,000	400,000	400,000	1562,000	400,000	400,000
Chemical lime and disinfectants	50,000	-	50,000	50,000	-	50,000	50,000	-	50,000
V. Others									
Charcoal (5 bags)	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Kerosene (10 gallons)	225,000	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500
Growth boosters	55,128	55,128	55,126	55,126	55,126	55,126	55,126	55,126	55,126
TOTAL CASH EXPENSES	**25,696,392**	**6,476,628**	**9,615,626**	**14,277,626**	**6,476,628**	**9,615,629**	**14,277,626**	**6,476,628**	**9,615,629**
Cash income A	15,146,000	9,500,000	17,000,000	17,000,000	9,500,000	17,000,000	17,000,000	9,500,000	17,000,000
Cash expenses B	25,696,392	6,476,628	9,615,629	14,277,626	6,476,628	9,615,629	14,277,626	6,476,628	9,615,629
Production profit/loss	-10,550,392	3,023,372	7,384,371	2,722,371	3,023,372	7,384,371	2,722,372	3,023,372	7,384,371

Exchange Rate: Buying Dollar (1 dollar to Le 4450 bank rate); Selling Dollar (1 dollar to Le 4300 bank rate – 2014)

Table 5: Cash flow analysis for 3 years (3 production cycles per annum possible)

Year	Costs	revenue	Incremental Benefit (1)	Discount Factor at 15% (2)	Net Present Value at 15% (3)	Discounted Costs (4)	Discounted Revenue (5)
1	41,788,649	41,646,000	-142,649	0.87	-124,104.63	36,356,124.63	36,232,020
2	30,369,883	43,500,000	13,130,117	0.76	9,978,888.92	23,081,111.08	33,060,000
3	30,369,883	43,500,000	13,130,117	0.66	8,665,877.22	20,044,122.78	28,710,000
					18,520,661.51	**79,481,358.49**	**98,002,020**

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