International Food and Agribusiness Management Review
Volume 16, Issue 1, 2013

Socioeconomic and Environmental Impact of Development Interventions: Rice Production at the Gallito Ciego Reservoir in Peru

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Abstract

Apart from direct economic impacts, development projects have complex social and environmental impacts among which sustainability plays a major role. The Gallito Ciego reservoir was built to increase and improve agricultural production at the Jequetepeque valley in Peru. Cost-benefit analysis of rice production from 1992 to 2007 is used to measure the immediate economic impact of the project. Also, a matrix of other relevant impact indicators is constructed to expose changes in the project's environment during its life cycle. The main conclusion is that, even though there is a significant positive increase in income from agricultural production, the social and environmental impacts are not necessarily positive.

Keywords: cost-benefit analysis, dams, development, Jequetepeque, rice.

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Introduction

Degradation of the environment and natural resources is not only caused by weak economic development, but it can also be generated by excessive economic development. For example, projects like dams and roads require the relocation of population, affecting economic activities and also creating stress to animals and plants around the zone. Furthermore, increasing population pressure and industrialization generates serious problems related to water, soil and other natural resources. These problems cannot be separated from the intervention and have to be taken into account in the development plan as economic development, social wellness, and environmental quality should be the pillars of development projects. A sustainability analysis must be incorporated to ensure social acceptability and maintain the original quality of the previous natural system (Barzev 2002). There must be a balance between these three components.

The Andes Basin Focal Project is an initiative to study the Andes system of river basins. The research done under this project tries to improve the knowledge and methods to grow more food with less water in an environmentally and socially acceptable way. Three big river basins are included in this system: Fuquene in Colombia, Ambato in Ecuador, and Jequetepeque in Peru.

In 1988, the national development institute of Peru (INADE is its acronym in Spanish) built the Gallito Ciego reservoir as part of the "Proyecto Especial Jequetepeque-Zaña (PEJEZA)". Its objective was to allow a better storage and regulation of the Jequetepeque River's water, thus increasing and improving the agricultural area at the Jequetepeque and Zaña valleys.

Agriculture is the main economic activity in the zone, but before the reservoir, it was characterized by high dependence on subsoil water availability and local rainfall patterns. This lack of dependable water sources resulted in unstable yields, which affected farm incomes and investment in the area. The most important crop in the basin is Oryza sativa (rice) representing 70 percent of the total harvested area (MINAG 2007). While rice production benefited from Jequetepeque's soil characteristics, it remained constrained by water availability. It is important to mention that rice production in the Jequetepeque basin represents one third of all Peruvian rice production and is the second one in terms of productivity (MINAG 2009a).

A study to measure the impact of the dam on the agricultural sector of the economy would be very useful for this area. This study focuses on the impact on rice production and on the broader impacts on the society and environment. According to the Peruvian department of agriculture (MINAG for its acronym in Spanish), Peru's annual rice consumption of 54 kg per capita is the highest among all Latin-American countries (MINAG 2009a). Peru is also a net rice importer.

The purpose of this paper is to evaluate the increase in rice production and productivity in response to increased availability of irrigation as a result of dam construction using a cost-benefit analysis, and to evaluate the evolution of the Gallito Ciego reservoir project's environment in terms of changes in five important variables/indicators at the zone. Two scenarios are analyzed: "Without the project" and "With the project".

Literature on Review

At the time this study was conducted, there was a lack of published studies addressing the impacts of the Gallito Ciego project in the Jequetepeque watershed. However, there are some independent unpublished studies and government reports on the watershed evolution after the project's completion the findings from which are used in this study. Here, we also review studies on the impact of other dam construction for comparison purposes.

A study by Martinez (1989) explored the possible negative impacts that the dam would generate in the near future. It is mostly focused on the relocation of families that lived near the dam and how there was going to be a crop switch process which could generate some traditional/cultural losses.

Two working papers by the Danish Institute for International Studies (DIIS) were published for the Jequetepeque watershed zone. For the first one, the objective was to identify key stakeholders in the management of the Jequetepeque watershed and analyze the different interests and issues which contribute to conflict and cooperation among them. The author examined the institutions establishing access to irrigation water and argues that a payment for environmental services must be considered (Raben 2007). For the second paper, a poverty profile for the upper part of the basin was developed. In it, they showed the relationship between water irrigation access and poverty levels (Gomez et al. 2007).

Wittwer explored two relevant projects about dams. In the first one, the author referred to the possible welfare impacts that the construction of the Traveston dam would generate in the Queensland area (Wittwer 2009). It was estimated that project would raise the present modest yield of existing catchment in Southeast Queensland by at least 70 giga-liters. The study also stated that the improvement in cost competitiveness of industries due to water supply would attract additional labor and capital to the region. The welfare impacts calculated using cost-benefit analysis, conditional on future rainfall patterns and water requirements over time, are estimated to be US$ 3.4 billion at a real discount rate of 5 percent. For the second one, the impact of irrigation water buyback in the Murray-Darling basin is addressed (Dixon et al. 2012). The results suggested that rather than a reduction, based on the increase in price of water, there would be an increase in the economic activity in the basin. The buyback policy would not be as hard on the environment as farmers would switch to less water demanding crops.

In 2009, a study assessing the progress of Public Financing Institutions (PFIs) in recent years was published. It focused on the application of environmental impact assessment mitigation and monitoring the large dam projects financed by those institutions. The key finding of this research is that multilateral PFIs have a better record regarding environmental safeguards in the dams they finance than bilateral PFIs (Caspary 2009).

Gunatilake and Gopalakrishnan (1999) stated that the benefits of water resource projects often fall short of original expectations because of sedimentation of the reservoirs. Their study estimated the cost of sedimentation in Mahaweli reservoirs including the impact on hydropower production, irrigation water supply, water purification, and loss of fisheries yields. The present cost of sedimentation is estimated to be US$ 26,406,620. They also argued that the benefits of prevention of reservoir sedimentation are inadequate to compensate for the costs involved. Using soil erosion control measures at farm level offers a better solution for reservoir sedimentation compared with de-silting.

Duflo and Pande (2007) studied the productivity and distributional effects of large irrigation dams in India. They found that, in districts located downstream from a dam, agricultural production increased and vulnerability to rainfall shocks declined. Food grain production in India nearly quadrupled in the last 60 years and the study attributed nearly 50 percent of this increase to the dam construction.

Study Area

The Jequetepeque basin is located on the north coastal side of Peru, between the parallels 7°6' and 7°30' south latitude; and the meridians 78°30' and 79°40' west longitude (Figure 1). It covers 4,372.5 km^2 located in two states: La Libertad (north area) and Cajamarca (west area).

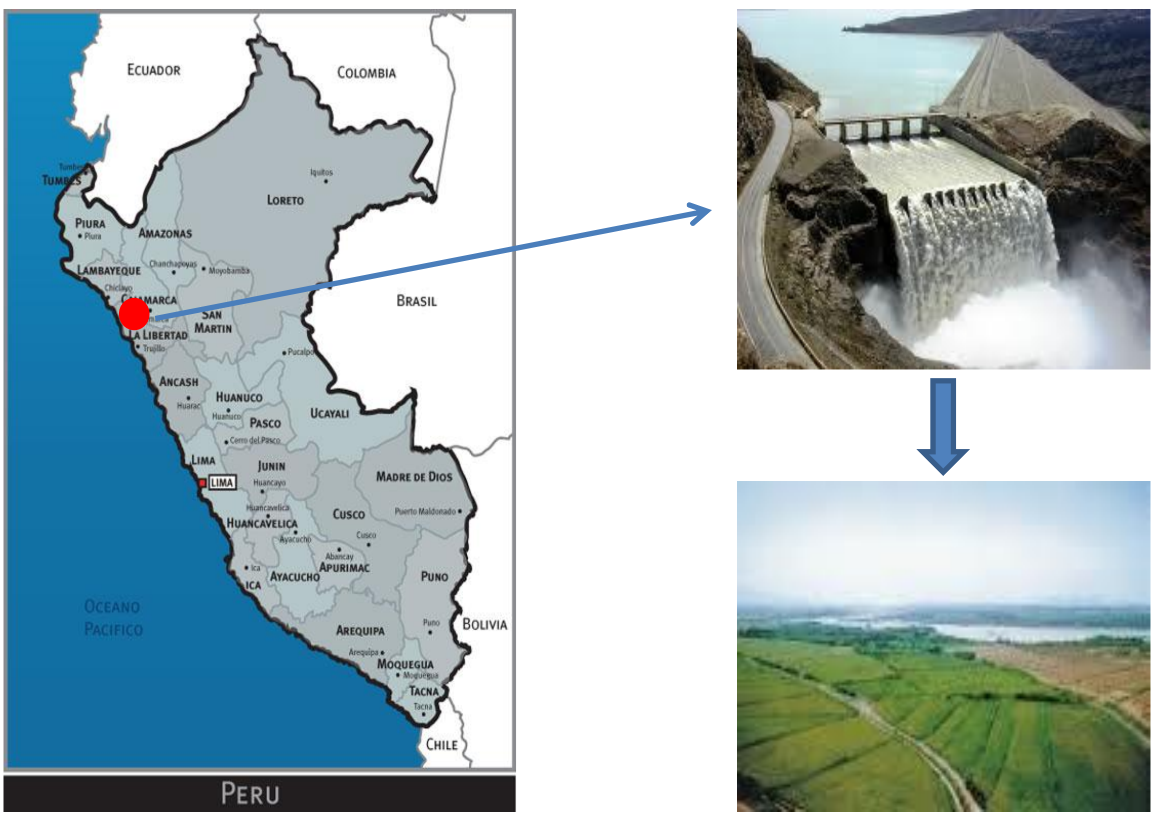

Figure1. Jequetepeque location (CONDESAN 2009)

According to national 1993 census, Jequetepeque basin population was 261,499: Half of them lived in rural areas and the other half in urban areas but 47 percent of the population worked in agriculture. Basically, the basin is divided in three sectors: low lands (valley), mid lands, and upper lands.

The upper part of the basin's annual rainfall is about 1000 mm. This part of the basin has stable precipitation which is relatively heavier between October and May. Meanwhile, the adjacent valley area receives almost no precipitation, except for El Niño summers. This low precipitation in the coastal area is due to the sea water temperature, whereas the weather in the upper part of the basin is influenced by the Amazon basin and the humidity coming from the Pacific.

The average annual discharge from the Jequetepeque River is around 816 millions of cubic meters (MCM) (CONDESAN 2009). As this discharge has relatively low volatility (between 777 and 825 MMC in the last 30 years), the hydrological regime of the Jequetepeque River can be considered stable (CONDESAN 2009).

The Gallito Ciego reservoir is located in the Yonan district, Contumaza province in the state of Cajamarca. Its average altitude is 350 meters above sea level. It is located in the low path of the Jequetepeque River, between the mid lands and the valley, forming a "cup" 12 km in length and 1.5 km in width. It is the second largest dam in Peru with a usable volume estimated at 400.4 MCM. The operation of Gallito Ciego has allowed the increase of water availability reducing by 75 percent the run-off of water into the ocean.

Within the valley sector, land use is divided in urban areas and poultry farms, farmland (agriculture), forest plantation, and land with no use. Rice is the primary seasonal (perennial) crop of the valley representing 70 percent of all the harvested land. Table 1 shows the use of the land.

Table1. Actual use of the land (valley)

Land use	**Area (ha.)**	**%**
Urban areas & poultry farms	1,353.59	1.91
Vegetables	50.82	0.07
Perennial crops	35,714.36	50.49
All year round crops	1,986.84	2.81
Forest plantations	552.75	0.78
Unused lands	31,081.13	43.94
Total	70,739.51	100.00

Source: CONDESAN (2009).

Except for rice, all other agricultural products are imported from other parts of the country or overseas. Jequetepeque's rice production also supplies Lima and some national markets in the north – Cajamarca, Trujillo, Chimbote and Chiclayo.

Annual irrigation water requirements at the low lands (in millions of cubic meters) are shown in Table 2.

Table2. Annual water irrigation requirement in millions of cubic meters (MCM)

Description	Supply	Demand	Surplus
Main season	640.68	602.59	38.1
Complementary season	78.73	7.89	70.83
Total	719.41	610.48	108.93

Source: Compiled by author from CONDESAN (2009)

Agricultural production at the area has substantially benefited from the dam construction. The irrigation supplied by the dam project has increased production by 50 percent.[1] The area within the reach of the irrigation project at the low lands covers 42,836 hectares, from which only around 36,000 (ha) are currently being used (CONDESAN 2009).

Methodology and Data Description

Measuring the aggregate impact of a project is a challenging task. The most straightforward approach is to measure the impact on each specific affected sector separately (i.e., economic (e.g., income), social (e.g., income distribution), and environment), and then add them together to obtain the total effect. This study focuses on the income impact from increased rice production. For this, two scenarios were compared: with and without the project.

Net present value (NPV) of net cash flow (NCF) is an effective tool to conduct cost-benefit analysis of a project whose returns and outlays are spread over time. The NCF is the difference between the gross income and the cost of production. The NPV is calculated as a sum of the annual discounted NCF. The purpose of discounting is to incorporate the time value of money into the analysis using a discount rate appropriate for the riskiness of a project, opportunity cost of funds, and time preference. Technically, the present value (PV) of future cash flow (I) is discounted by dividing it by the discount rate (r) to the power of the number of time periods (t) from present. That is:

$$(1)\quad \mathrm{PV}[I] = I/(1+r)^{t}$$

The NPV analysis was used for the first part of the study, which focuses on rice producers' monetary welfare through comparison between the scenario with and the scenario without the project. Rice was selected because it is the most important crop in the area and also because the main goal of the irrigation project was to increase the rice planting area and productivity in the zone. Income and production cost (income statement) dataset for this crop from 1992 to 2007 was assembled using cost data collected from the Gallito Ciego Reservoir Camp (PEJEZA 2009) and income data collected from the MINAG (2009b) website and the MINAG Trujillo (MINAG 2009c) regional website[2]. The income statements were built using annual average production cost for a typical producer in the area (mid-high technology producer) and aggregate level

[1] According to PEJEZA website. www.pejeza.gob.pe

[2] Even though the project started on 1988, data prior to 1992 were not considered reliable as the Peruvian currency suffered severe devaluation caused by inflation problems. A change in currency denomination occurred in 1991, passing from "Inti" to "Nuevo Sol".

income data[3]. The production costs are standardized and include the following items: seed, fertilizer, agrochemicals, transportation, mechanization, labor, draft animal power, threshing processes, financing, indirect costs, and water usage. The income data include: prices, yields, and area harvested (it is assumed that all production was sold). As the objective is to calculate the cost-benefit for rice producers, capital costs of the dam were not included in the NPV because the dam construction was fully financed by the government[4]. Ideally, net benefits from the dam construction should be computed as the difference between the NPVs of gross benefits and the capital investment (construction costs) and subsequent maintenance costs. However, in this situation, it is hard to assign a monetary value to all the benefits and the costs of the project and those include social and environmental impacts, some of which may be long lived. The social impacts include the well-known impacts of higher income on health, education, and labor productivity. Higher farm incomes may also contribute to infrastructure development which has a multiplier effect on the local economy. The environmental impacts are multi-dimensional and include the impacts on soil quality and runoff which, in turn, affects eco-systems and so on. Thus, we do not attempt to perform a standard cost-benefit analysis due to the multi-dimensionality of the project impact. The analysis was made in U.S. dollars using the exchange rate for each year provided by the Central Bank of Peru.

For the “with project” scenario, the actual income statements are used. The production costs included a water expenditure item, which refers to water access/usage provided by the dam (a charge per cubic meter of water used). This value was established at the beginning of the project by the government and includes the investment, operation, and maintenance cost of the dam.

For the “without project” scenario, the NPV is calculated under several assumptions:

- As it used to be before the project, only half of the hectares are used in production
- An average yield obtained over the last five years before the project is used also assuming an annual increase in productivity of 1 percent. The rice price per kilogram each year is the actual market price reported for the given year.
- No other major changes have occurred in the area so that the costs incurred are the same used for the real scenario but only without the entire water cost component.

For the NPV calculation under both scenarios, a discount rate of 4 percent was used. As the discount rate is reflecting the opportunity cost of capital and the riskiness of a project, and the actual interest paid on financing it, this value was chosen to correspond to the interest rate of the Central Reserve Bank of Peru to reflect the time value of savings deposited by the producers at the bank and also the allegedly low rate of time preference by rural investors (Belli et al. 1998; Raboin and Posner 2012).[5] Also, an income tax of 30 percent was applied as it is required for every business in Peru. For both situations, a cost-effectiveness analysis was performed.

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[3] Aggregate level income data: in farm paid prices, area harvested, and yields per year for each rice producing province at the Jequetepeque area.

[4] The total cost of the dam was 164 millions of U.S. dollars.

[5] An alternative of imputing a high discount rate (10-30 percent) used in microfinance literature is based on microfinance interest rates (individual farmer lending). Considering the nature, financing, and beneficiaries of the project in question, those high rates are not used in the discounting calculations.

In addition, the Impact Monitoring and Assessment (IMA) tool proposed by the Centre for Development and Environment (CDE) and the German Technical Cooperation (GTZ) (Herweg and Steiner 2002) was used. The IMA is as an instrument of quality control throughout the project's life cycle in order to better adapt project activities to a changing context. In here, a radar (also called "spider" or "amoeba") graph allows the visualization and comparison of relevant indicators in different timeframes. In addition to the "with project" and "without project" scenarios, an *expected* output scenario predicted at the beginning of the project is included to measure the accuracy of the real outcome. A relevant characteristic of this tool is that it has to include indicators reflecting the three components for a project to be sustainable: Economic, Ecological, and Social (Dumanski, Steiner, and Herweg 2000; Herweg and Steiner 2002).

The indicators chosen are as follows: rice yield, water availability (expected dam life), water irrigation efficiency in rice production, population annual growth rate in la Libertad state, and quantity of soils with salinity issues.

With available information from the project background and simple agronomic knowledge, the scales of indicators were built and are shown on Table 3.The scale range is from 5 (very good) to 1 (very poor). In here, the expected output is scaled to back to reflect the specifics of the Andean region – the value of 4 is considered a good value as development projects look for the best balanced feasible outcome. For example, even though expected water irrigation efficiency in rice production of 75 percent (DEJEZA 1977) would be considered average (or 3) in similar projects, that was the feasible expected value at the end of this project and it will be considered a 4 (good).

Continuing with the assembly of Table 3, according to the FAO (2007) data, the average yield for rice in coastal zones is between 8,000 and 9,000 kg/ha. The latter value is used for the expected value for rice yield under the "with project" scenario. After accounting for predicted sedimentation, the usable expected capacity of the dam was set at 400 MCM (PEJEZA 1999). According to Sanchez (1999), the annual population growth rate expected at the valley after the project was 3.25 percent. According to the executive management of the project (DEJEZA for its acronym in Spanish) the expected value of rice irrigation efficiency after the project was 75 percent (DEJEZA 1997). Finally, because of the intensive usage of water and rice cultivation practices, the amount of soil with salinity problems was expected to increase. The expected value assigned by "Apoyo a la Política de Desarrollo de Selva Alta" (APODESA 1994) was a 3 percent increase in salinity – from 28.5 percent before the project (ONERN 1988) to 31.5 percent.

The data for the two scenarios rely on the measurements from previous studies. Most of them come from the public sector research. The base year is 1987 and become the "without project" scenario. For the "with project" scenario, the end of the first stage of the project (2006) or the nearest record available for each specific variable was used. The values are shown in the results' section.

Table 3. Scales of indicators

Indicators	Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Water availability (MCM)	<150	150-249	250-349	350-450	>450
Rice yield (kg/ha)	<6,500	6,500-7,499	7,500-8,499	8,500-9,500	>9,500
Water irrigation efficiency (%)	<50	50-59	60-69	70-80	>80
Population Growth rate (%)	<2.0	2.0-2.4	2.5-2.9	3.0-3.5	>3.5
Soils with salinity (%)	>38	36-38	33-35	30-32	<30

Source: compiled by author – DEJEZA, FAO, PEJEZA, Sanchez, APODESA, ONERN.

Results

The NPVs for the two scenarios are very different. The "without project" (baseline) scenario would generate negative returns (losses) of US$ 4,201,119. Under the alternative ("with project") scenario, the NPV was positive (US$ 69,500,051), which indicates that the rice producers benefited substantially from the project. Because of the negative value under the "no dam" scenario, cash flows per year are analyzed.

Table 4 shows the cash flows from rice production for each year. It can be seen that in the "without project" scenario some of the cash flows are positive and others negative. The year 2007 was an outlier for several reasons that are explained in the next paragraph. If the outlier year is taken out, the NPV of the cash flow becomes positive (US$ 4,224,409).

Table 4. Cash flows and cost-effectiveness of rice production under the two scenarios

Year	Without project	With project	Incremental flow	Cost effectiveness
1992	-738,065	-12,147,997	-11,409,933	-41.59%
1993	301,989	2,212,992	1,911,003	24.56%
1994	-7,443,835	-8,738,182	-1,294.35	24.13%
1995	-2,949,932	-2,656,615	293,317	-6.64%
1996	3,579,323	19,225,928	15,646,604	83.03%
1997	2,332,790	11,081,596	8,748,806	41.35%
1998	7,666,447	14,543,989	6,877,542	83.53%
1999	-1,235,183	5,021,336	6,256,519	19.64%
2000	391,468	9,762,284	9,370,816	50.76%
2001	731,822	15,062,435	14,330,613	70.72%
2002	-2,126,824	3,659,952	5,786,776	15.83%
2003	-1,955,486	5,481,835	7,437,322	24.20%
2004	8,176,257	38,475,429	30,299,172	187.03%
2005	1,602,554	11,624,926	10,022,372	52.25%
2006	-143,596	8,436,723	8,580,319	31.79%
2007	-15,173,901	-18,957,686	-3,783,785	-20.57%

Incremental cash flows per year are all positive except for 1992, 1994, and 2007. Through a personal conversation with the CEO of the MINAG office in Trujillo, Segundo Vergara, the losses in 1992 are explained by a shortage of water supply from the Jequetepeque River. For that year, the annual water mass from this river was only 338 MCM generating suboptimal outputs. In 1994, the price of rice went down from 0.45 to 0.32 soles (0.23 to 0.15 US$) per kilogram affecting the revenues. The big loss in 2007 is explained by a considerable increase in gasoline prices. This increased production expenses from US$ 37 million in 2006 to US$ 92 million in 2007, whereas production did not increase proportionally (276 and 236 million of ton respectively). Also in Table 4, a cost-effectiveness measure was obtained as a ratio of the profits and total costs. It was on average 40 percent.

Table 5 shows the most important indicators in the area served by the dam under the two scenarios, also listing the expected values. A measure of water availability (dam life) is important because it reflects the years the farmers will benefit from the project. A bathymetry study at the dam in 1999 showed that the volume of total estimated sedimentation was around 65 MCM, with the annual average of 3.4 MCM. This reduced the useful life of the dam to 33 years instead of the expected 50 (Cobeñas 2007). The rice yield indicator allows quantification of the real gains in agricultural output. According to MINAG (2007), the rice yield for the zone before the project was 5,975 Kg/ha but almost doubled to 10,108 Kg/ha in 2005. Irrigation efficiency in rice production in the area was measured using three efficiency components: delivery, distribution, and application. Delivery rates are correlated with water recuperation rates and altitude. Distribution refers to the deficiencies of a particular irrigation canals and its extension.

Table 5. Project Values

Variable	Without Project	Expected	With Project
Water availability	0	**400**	335
Rice yield	5,945	**9,000**	10,108
Irrigation efficiency	40%	**75%**	73%
Population Growth rate	2.10%	**3.25%**	1.70%
Soil Salinity	28.5%	**31.5%**	34%

Source. compiled by author – Cobeñas, MINAG, DEJEZA, CES, Sanchez, INEI, ONERN, PEJEZA.

Application relies on climate data, information on the crops in each sector (using FAO's CROPWAT program), and the requirements for their vegetative stage (CES 1997). A study about economic and technical feasibility by DEJEZA (1977) showed that the total irrigation efficiency before the project through rural irrigation canals was around only 40 percent. There were no very recent studies about the water efficiency so research findings from CES (1997) were the best proxy. According to those results, water use efficiency increased to 73 percent. Big projects like dams may have mixed impacts on population. Dams can increase population density around the area because of the perceived economic growth but can also decrease it because of the relocation of people who lived in the path of the dam. The study made by Sanchez (1999) under the supervision of INADE established that the population growth rate in the valley during 1981-1993 was 2.1 percent which is the rate also given by the Peruvian National Institute of statistics (INEI) for the whole state of La Libertad. The INEI also stated that the actual growth rate for the state from 1993-2007 was 1.7 percent (INEI 2007). Salinity problems are very common in in rice production as it is very water intensive. This is a big issue as high salinity can decrease productivity and soil quality. The national office for natural resources evaluation (ONERN) determined that the area covered by soils with salinity problems at the beginning of the project was around 28.5 percent. The value at the end of the first stage of the project taken from the document provided by PEJEZA (2005) is 34 percent. A radar graph described in the previous section and constructed using these values is shown in Figure 2 for better exposition. The farthest away from the center represents a better outcome.

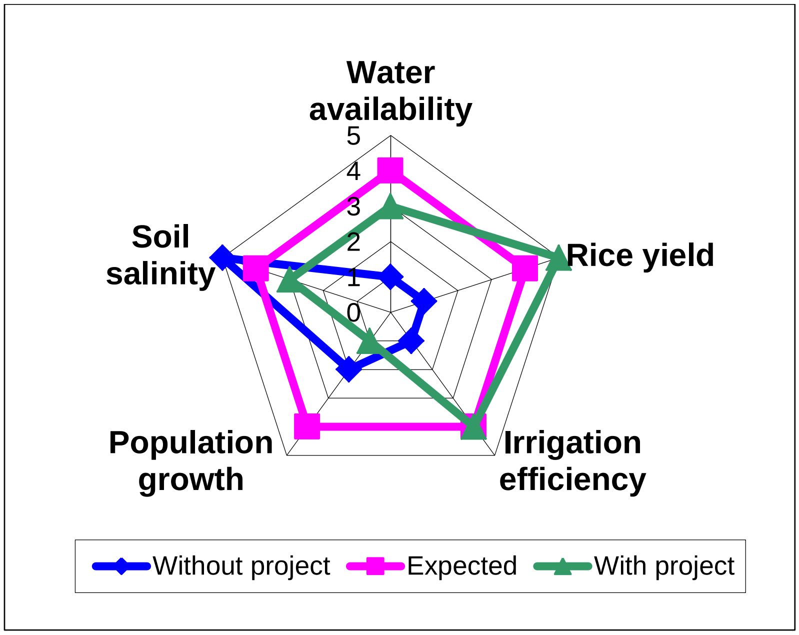

Figure 2. Radar Graph

The comparison of the historical data, predicted outcomes, and real outcomes at the end of the first stage of the project shows that the number of years of water availability from the dam was smaller than estimated due to extra sedimentation. At the same time, the estimation of the gains in irrigation efficiency at the beginning of the project was accurate. With respect to agricultural outputs, the estimates matched the actual rice yields. The population growth rate was overestimated, whereas the increase in salinity was underestimated. According to the numbers, the no dam scenario looks significantly worse than the alternative.

Discussion

Despite the coverage areas being different, this study's NPV of US$ 69,500,051 obtained can be related to US$ 3.4 billion estimated by Wittwer (2009) because they are both positive. Nevertheless, project's coverage was different and, in the case of Queensland, all the possible impacts were estimated, including electricity generation and job generation (income distribution). This study, on the other hand, only included the agricultural sector focusing on a single crop—rice—because the main objective of Gallito Ciego was to increase the agricultural production in the zone. We have confidence in our results because of the small area covered by the project. Another difference is that the project in Queensland was determined to generate higher rates of migration to the development zone because it has a smaller population density and because the area is significantly bigger than the one in northern Peru.

According to PEJEZA, the powerful effects of the 1997 El Niño were mostly responsible for Gallito Ciego increased volume of sedimentation. Putting some numbers on it, the annual average amount of solids moved by the Jequetepeque River during the period of 1943–1998 was 2.9 MMC instead of the 1.7 MMC estimated before implementation of the project. For the period of 1968–1998, this amount is determined in 3.4 MMC which is the reason why the useful life of the dam is reduced to 33 years instead of the original 50 years. If the global warming trend continues, leading to increased frequency of El Nino and La Nina cycles, heavier precipitation should be expected in the region, which would increase sedimentation and lower the estimated future benefits of the project, unless further investments are made to remove sediments from the dam.

Regarding the annual population growth rate for the state of La Libertad, the expected value of 3.25 percent was very upward biased (compared to the real outcome of 1.7 percent). The average population growth rate for that period in Peru was 1.6 percent, being 2 percent for the state of Lima (the capital state) and 3.5 percent the state of Madre de Dios (the highest value and definitely an outlier). The values for the most important provinces in the valley belonging to the state of La Libertad, Chepen and Pacasmayo, were only 1.3 percent and 1.5 percent respectively. The average value for the state of La Libertad was improved by the province of Viru (located in the south of the state) whose growth rate was 5.1 percent. Viru is included in other bigger irrigation project called “Chavimochic”.A possible explanation for not reaching the expected population growth rate can be that the time period considered is too short. However, this does not explain the reduction in the rate reinforcing the idea that a big development project might increase the population growth ratio at the location but other factors like culture, government policies, and the economic performance of the whole country should be taken into account.

In general, dams tend to have a negative impact on the broader environment even when they produce specific benefits, such as improved agricultural production. Increasing water availability for artificially low prices can exacerbate the environmental problems by increasing production in ways that accelerate soil erosion, which would eventually lead to long-term losses in productivity. This study showed a 6 percent increase in the quantity of soils with salinity problems at the area. In 1999, Sanchez showed that 30 percent of the area at the Jequetepeque basin had high intensity and 36 percent of it had moderate intensity erosion. Hansen and Hellerstein (2007), using the replacement cost method, showed that among 2,111 watersheds in the U.S., a one-ton reduction in soil erosion provides benefits ranging from zero to US$ 1.38. They also did a comparison between lower and higher soil erosion levels (1997 and 1982 respectively) and showed that the lower level erosion conserved US$ 154 million in reservoir benefits. Gunatilake and Gopalakrishnan (1999) used a cost-benefit analysis to estimate the cost of reservoir sedimentation in Mahaweli reservoirs. They estimated the sedimentation cost present value to be of US$ 26,406,620. A model like the one used by Dixon et al. (2012) might be applicable to mitigate the negative externalities on soils as it shows that an increase in irrigation water prices leads to farmers switching to less water demanding crops without compromising agricultural outputs.

Conclusions and Recommendations

This paper examines the impact of the construction of Gallito Ciego reservoir using two tools: a cost benefit analysis for the rice producing agricultural sector and a spider graph showing the changes in the project's environment after the implementation. It was found that the NPV of the benefits to the rice producers after construction of the dam was US$ 69,500,051 compared to a hypothetical scenario of no project (no dam construction) with the NPV of US$ -4,201,119. The cost-effectiveness ratio of the project was around 40 percent. At the same time, the dam project led to a 6 percent increase in soil salinity in the area, which is almost double of the expected increase, and the population growth rate in the zone covered by the project (1.7 percent) was lower than expected.

The estimation of the NPV of the dam irrigation project for rice production in the Jequetepeque watershed suggests an aggregate positive impact. However, the study shows that estimations of the environmental and social impacts were too optimistic relative to the actual cost. This reinforces the idea that, in developing countries, environmental and social components are not getting the attention they deserve, leading to greater risks of falling into poverty traps through overexploitation, soil depletion, or social conflicts.

A replacement cost study might be explored in the future to measure the environmental impact of the dam, particularly the impact on soil quality. This technique uses the cost of returning the environmental component to its original condition as a way to express the environmental damage in monetary units.

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