Assessing trends and changes in irrigation performance
The case of Samaca Irrigation Scheme, Colombia

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Paper presented to the IIMI, ILRI, IHE and INCYTH-CRA
International Workshop on Irrigation Performance
3-7 November, 1997, Mendoza, Argentina

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ABSTRACT

A distinction can be made between internal and external performance indicators. System managers might use internal indicators (like adequacy, timeliness and reliability) to evaluate actual results with targets in order to improve services to water users. Researchers and policy makers might be interested in a rapid, data extensive, performance evaluation in order to assess which types of systems in certain environments function well and which less. For the latter purpose external indicators which focus primarily on main outputs and inputs like water and land, were developed. IIMI identified a minimum set of nine external performance indicators, covering agricultural, water related and financial issues. This set of indicators supplemented by 4 additional indicators was applied to Samaca Irrigation Scheme in Colombia over a time span of 11 years.
The study shows that the set of external indicators lends itself not only for cross system comparison but also for analyzing developments in performance over time within one system. The application of the set provides a sound overview using simple calculation methods and basic information on irrigation, agriculture, climate and financial management. However, for establishing in-depth cause and effect relationships between observed performance and internal management features, additional background information is essential.

[1] The authors acknowledge the excellent work done by Luis Alberto Mora who did the major part of the data collection.

1. INTRODUCTION

1.1 Background

Performance evaluation can be executed for several purposes and by distinct groups of professionals. Depending on the objectives of the performance appraisal either internal or external indicators, or a combination of both, can be adequate. Farmers and system managers can measure performance by comparing actual results to planned targets in order to improve irrigation services to water users, making use of internal indicators. These indicators mainly deal with the irrigation delivery system in terms of adequacy, reliability of flow rates, timeliness, dependability and equity of distribution (Murray-Rust and Snellen 1993 and Rao 1993).

Researchers and policy makers might want to use indicators to compare the performance of different types of systems in various settings. Internal indicators do not lend themselves well to cross system comparison (Molden et al., 1997). Due the site specific character of management practices and targets, results often are hard to compare with other systems and other countries. Furthermore, the measurement of the internal indicators tend to be data intensive. To overcome these problems IIMI identified a minimum set of external performance indicators (Perry, 1996). External indicators focus on outputs and main inputs of the system like land and water. They give little insight in the internal management processes leading to the observed outputs but will identify which types of systems in which setting function well and which less, using a minimum of data. The consistent application of the minimum set of indicators in the different parts of the world will allow for comparisons between different schemes within and across countries and regions. In this way relative performance standards can be developed per type of irrigation scheme to facilitate evaluation of individual systems. The indicators might also prove useful to relate performance to water management practices.
IIMI's minimum set of indicators covering agricultural, financial and water related issues are currently being applied in several countries like Mexico, Colombia, Egypt, Morocco, Sri Lanka and India. Kloezen & Garces (1996) used the indicators to evaluate spatial variation in the performance in different sectors within one scheme in Mexico, while Molden et al.(1997) made a comparison between several schemes throughout the world. In this study the minimum set of indicators was applied to the Samaca Irrigation Scheme in Colombia over a time span of 11 years (1986 - 1996). A temporal analysis of performance using the indicators was accomplished and values of the indicators were compared with those for a range of schemes throughout the world, as described by Molden et al. (1997).

1.2 Methodology

The study was centered around the questions:
What are the trends in performance of irrigated agriculture in Samaca Irrigation Scheme ?
Is the minimum set of indicators as identified by IIMI a suitable tool to describe and analyze temporal variation in performance in Samaca Irrigation Scheme ?

To answer these questions the major changes and trends in agriculture and irrigation management in the Samaca Irrigation Scheme over the last decade were identified (chapter 2). Next the indicators of the minimum set were calculated for each year and their temporal variation was analyzed or: how are the changes reflected by the indicators ? (chapter 3). The set of indicators was supplemented by 4 indicators which could be computed with the available data and which provided additional insight in performance issues.

The indicators, divided in three groups (agricultural, financial and water related) are listed below. The indicators printed in italic are not included in IIMI's minimum set.

Agricultural:

1. Irrigation intensity
2. Gross value of output per hectare of the command area
3. Gross value of output per hectare of the irrigated area
4. Gross value of output per unit of irrigation applied
5. Gross value of output per unit of water consumed

Water-related:

6. Relative water supply
7. Relative irrigation supply
8. Water delivery capacity

Financial:

9. Fee collection rate
10. Financial self-sufficiency
11. Gross return on investment
12. O&M expenditures per unit of land
13. O&M expenditures per unit of water

A detailed description of each indicator and calculation method is given in annex 1.

1.3 Data collection

Mainly historical data from secondary sources like government offices, commercial centers and research institutes were used. As stated by Small and Svendsen (1992) the use of indirect or secondary data may distort performance assessment if it is believed that the results will affect job performance ratings. Agricultural yields might be estimated on the high side by agricultural engineers working in the area due to their professional bias towards successful commercial farmers rather than small subsistence farmers in the hills. Ditch keepers might report volumes of water delivered closer to the desired or planned than to the actual values. However, obtaining reliable data on direct measures is often difficult and costly. It is necessary to balance the increased value of the more accurate and reliable information provided by the direct measures of performance with the additional cost of obtaining that information. Moreover, IIMI's involvement in Samaca only dated from 1995 onwards while the performance analysis was executed over a time span of 11 years. To overcome above mentioned problems data were carefully double checked with information from other sources and compared with values reported for other similar systems nearby. The obtained data are considered reasonable reliable for this analysis.

The Colombian Irrigation Agency at regional as well as at national level (INAT[2]) could provide data on cropping patterns and water use. Data on financial issues like budgets, expenditures, water fee collection, outstanding debts and personal management were available with the Water Users' Association in Samaca. Crop yields and local prices were collected at a nearby agricultural commercial center (CORPORABASTOS) where the majority of the crops are traded. The International Potato Center (CIP, Peru) provided data on potato prices at world market level. Financial data like inflation and exchange rates were subtracted from the IMF publications International Financial Statistics Yearbook for each year. Crop water demands and net irrigation requirements for individual crops and for the scheme as a whole were calculated with CROPWAT (FAO 1992 and 1993)[3]. For the estimation of the effective rainfall the formula developed by the USBR/USDA-Soil Conservation Service[4] was used. The Colombian Ministry of Environment, responsible for the climate station situated in the command area, had a complete and up-to-date data base on temperature, precipitation, wind speed, solar radiation and relative air humidity for each year. Actual canal capacities and the amount of irrigation water applied in the last semester were measured in the field.

All data were processed with Excel 5.0. To define if the differences in mean values before and after an incident are statistically significant, the simple paired t-test was used. Correlation coefficients and trend lines were calculated with Excel in-built statistical Tool-pack. Data utilized to compute the indicators are summarized in annex 2.

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[2] INAT: Instituto Nacional de Adecuacion de Tierra

[3] Latest version downloaded from website ftp://ftp.fao.org/FAO/AGL/AGWL/CROPWAT/

[4] Refer FAO 1992: $P_{eff} = P_{tot}(125 - 0.2\, P_{tot})/125$ for monthly $P_{tot} < 250$ mm

$P_{eff} = 125 + 0.1\, P_{tot}$ for monthly $P_{tot} > 250$ mm

1.4 General description of the scheme

The Samaca Irrigation Scheme is situated in Eastern part of the Department Boyaca in central Colombia (refer to figure 1 for map). Altitudes in the command area vary from 2600 to 3000 m. The command area covers approximately 3000 hectares of which 54 % consist of flat land while 46 % is hill area.

The mean daily temperatures vary little over the year and average 13.8 °C. The rain fall pattern is extremely irregular within the year as well as over the years. The mean yearly rainfall over the studied period (1986 - 1996) is 690 mm with two pronounced wet periods in October - November and April - May. Occasional hail storms occur in the dryer periods. The potential evapotranspiration[5] which hardly shows any variation throughout the year, amounts to 1020 mm on year basis. Figure 1 shows that November is the only month in which the mean effective rainfall exceeds the evapotranspiration. In the other months irrigation will be required to meet crop water needs. However, due to the enormous fluctuation in precipitation the irrigation needs vary widely between the years. Table 1 summarizes details on climate data for the study period.

The main crops grown in the area are potato, onion and green peas. On a smaller scale vegetables (red beat, cabbage and carrots), wheat, maize, beans and barley are grown. At present some 2000 farmers are benefiting from the scheme. The average land holding 3.5 hectares in the plain and 0.9 hectares in the hill area.

In the valley the agriculture has a commercial character while in the hill part subsistence farming dominates. About 30 % of the total command area is currently used for (irrigated) pasture, mainly situated in the hill area.

The system receives irrigation water from 2 serial reservoirs with capacities of 4.7 and 1.5 Mm^3 .The reservoirs receive water from precipitation falling on the catchment area. Two lined secondary canals with a capacity of 250 and 400 l/s convey water along the contour line to the hillside areas. The valley receives water from the river that originates from the reservoirs. This river is used as main canal and drain at the same time.

Farmers in the valley receive the water on demand. If they need water they submit a written request to the ditch keeper. Based on the demands the management makes a weekly schedule of delivery detailing time and duration. It should be noted that most farmers in the valley are fairly independent of the management concerning exact amount and timing because most of them constructed ponds on their plots to store the water temporarily. The water is extracted with motor pumps connected with sprinklers.
The hillside area is divided in irrigation units each having their own storage tank. These tanks are small (12 to 36 m^3) and mainly used for domestic purposes. In theory there is a continuous water supply to the units. However, because of technical problems (design errors) nearly half of the units are forced to rotate the water.

[5] ET o according to Penman-Monteith, calculated with CROPWAT

Water fees are fixed on the basis of land area, independent of the volume actually used. There are two different fees: one for the plain area (45 US$ per ha, 1996) and a lower one for the hill area (25 US$ per ha, 1996). Farmers in the valley pay more because generally the commercial farming in the valley requires more water than the subsistence type of farming in the hills. Everyone with land in the command area is obliged to pay water fees regardless the fact whether the land is actually irrigated or not.

2. TRENDS AND CHANGES

2.1 *History of the scheme*

The biggest and oldest of the 2 reservoirs was built in the middle of the last century by a textile company who used the water to generate electricity. After the retention wall broke down farmers in the region decided to ask the government for credit to rebuild the wall and construct canals which would allow the use of water for irrigation. The construction of the reservoir and the main 2 canals finished in 1941. The system was initially administrated by the Water Department and later by Water and Electricity Institute.
In 1966 the Colombian Institute for Agricultural Reform took over the system and initiated some technical improvement in the canal and drainage system. Ten years later the Colombian Institute for Hydrology and Land Improvement was created and took over responsibility for the operation, management, maintenance and administration of the system. During this period the second reservoir was built and many improvements in the infrastructure were realized. These investments were paid by the government agency. In late 1992 the government agency transferred the system's management to the users. The entire system including reservoir and main canals was transferred.

2.2 *Trends and changes during the last decade*

A continuing trend in agriculture in Colombia is the shift from subsistence to commercial farming. Over the last decade Colombia's economy has been liberalized: importation taxes and exportation subsidies were reduced substantially while subsidies in agriculture were cut or reduced. Due to this opening-up of the market local farmers had to compete with imported products. On the other hand, agro-inputs became more widely available at lower prices. This resulted in a change in attitude towards farming: farmers started producing for the market rather than only for subsistence and increasing the use of agro-chemicals. Consequently, crop yields over the last decade show a rising trend.
The first two changes as described below which influenced management and agricultural practices in Samaca Irrigation System could be seen as specific events in this general process of economic liberalization.

A. Changes in cropping pattern

figure 2

Until the late 80s barley was a profitable crop in Samaca because the nearby beer factory was offering a good and steady price. However, with the opening of Colombia's economy the beer factory started to import cheaper barley from outside Colombia. This caused a dramatic reduction in price and area cropped with barley. At present it is mainly cultivated for own consumption.

In the second cycle of 1989 onion was introduced as a cash crop in the system. The deep loamy soils and the moderate climate appeared to be suitable for this crop. Good access roads and nearby markets made it easy to commercialize. Potato and onion are now the most important crops grown in the area. Onion prices fluctuate considerably from one month to another and growing this crop involve risks: one season the farmer may make high profits while the next season (s)he will lose money. Another problem is the frequent occurrence crop diseases mainly caused by monoculture.

B. Irrigation Management Transfer

In October 1992 the management and administration of the Samaca Irrigation System was transferred to the Water Users' Association. This was done as part of a national program to reduce government subsidies and expenditures in the irrigation sector and to transfer responsibilities from government to the direct beneficiaries. The Irrigation Management Transfer in Colombia started in the 70s when 2 systems (Saldana and Coello) were transferred to the users on their own request. Farmers claimed that they were able to manage the systems more efficiently and at lower costs than the government agency (Vermillion and Garces 1996). During the 80s no irrigation systems were transferred. Around 1990 the government launched a nation wide program to transfer irrigation systems. Samaca Irrigation System was the sixth scheme transferred under this government initiated program. The IMT process in Samaca started in 1991 when the water fees paid by the beneficiaries were raised with 170 % in order to increase financial self-sufficiency and to reduce government expenditures. In the same year the negotiations between the Water Users Association and the government agency started about the conditions of transfer. The negotiation process took one year. The IMT document was signed in October 1992 but it was only in January 1993 that the WUA really assumed the full management responsibilities.

C. Abolishment of the volumetric fee

Until 1990 the scheme used a volumetric water fee per cubic meter of irrigation water on top of the fixed fee per hectare. The fee amounted to approximately 2 to 3 dollars for 1000 m^3 (1995 constant prices). Around 15 % of the total income from water fees was derived from the volumetric fee. The volumetric fee was abolished by the irrigation management because of practical reasons: firstly, because of the high administration costs. Secondly, because reported water volumes could easily be manipulated by ditch keepers, as accurate measuring devices were not available.

The abolishment of the volumetric fee coincides with a jump in area covered with irrigated pasture. Apparently many farmers decided to use their fallow land for a water consuming but low value crop like pasture as soon as the water charge became independent of the actual volume utilized. Over the last three years the area covered with irrigated pasture is decreasing while potato and onion are gaining importance.

In the following chapter a description will be given of how the above mentioned developments are reflected in the performance indicators.

3. PERFORMANCE INDICATORS

The minimum set of consists of nine indicators covering agricultural, financial and water related issues (Perry 1996). For this analysis the set was complemented by 3 indicators describing the financial performance in more detail. Annex 1 gives the definitions of the indicators used in this study. Annex 2 provides an example of how the indicators were computed while annex 3 summarizes the data required for the calculation.
The values of the computed indicators are used to compare performance of the Samaca Irrigation Scheme with 18 irrigation systems located in 11 countries around the world (for details on this cross country comparative performance study refer to Molden et. al., 1997).

3.1 Agricultural indicators

A. Irrigation intensity

figure 3

The average irrigation intensity defined as the irrigated area divided by the command area, fluctuated around 0.85 during the late 80s. Between 1990 and 1991 the irrigated area increases rapidly bringing the irrigation intensity to an average of 1.65. The sudden rise coincides with the abolishment of the volumetric fee and the introduction of onion as a new cash crop. The abolishment of the volumetric fee lead to a dramatic increase in irrigated pasture while the introduction of a new cash crop (onion) resulted in an increase of area cultivated. The irrigation management transfer had no visible impacts on irrigation intensity. The jump occurred before the transfer.

B. Standardized gross value of production per unit of land

figure 4

The general trend in the standardized gross value of production (SGVP) per cultivated area is a rising line, mainly attributed to a general increase in yields of the two main crops, potato and onion. This can be explained by the changing attitude in farming (from subsistence to commercial) and improved agricultural inputs. The outputs in US dollars rise from around 1,500 US$ per hectare during the second half of the 80s to 2,500 US$ per hectare[6] in the last few years. In 1991 the SGVP dropped because farmers increased the area with irrigated pasture (low value crop) as a result of the abolishment of the volumetric fee. After 1992 the SGVP is picked up again as high value crops like potato and onion gain importance at the expense of pasture.

During 1986 to 1989 the SGVP per unit command area is slightly lower than the SGVP per unit cultivated area since the irrigation intensity is smaller than 1. After the abolishment of the volumetric fee and the introduction of onion the irrigation intensity rises substantially and consequently the SGVP per unit command area shows a jump. In 1995 the SGVP leaps up again, mainly by sustained yield improvements of potato and onion (the two main crops grown in the area). The SGVP per unit command area rises from less than 1000 dollar per hectare in 1986 to well over 4000 dollar per hectare in 1996 (constant dollars).

Comparing the values of SGVP per unit of land with those of other schemes throughout the world, Samaca ranks within the upper 25 % of the systems studied (Molden et al. 1997). It should be noted that the SGVP is a measure of productivity of the scheme and as such indicate little about individual farmers' income which may in fact rank much lower because onion requires high fertilizer and pesticide inputs and involves a lot of risks.

There were no visible impacts of Irrigation Management Transfer on the SGVP. Agricultural production depend on many factors like climate, inputs, diseases and price policies. Irrigation management is only one of the many factors having an impact on the system's agricultural output. Furthermore, there is little evidence that farmers changed agricultural practices because of the transfer. This was illustrated by the results of a recently held questionnaire in which farmers were asked about the transfer: 68 % of the

[6] constant dollars, base year 1995.

respondents claimed that they did not know what transfer meant, or could not remember (Giraldo 1997).

C. Standardized gross value of production per unit of water

figure 5 and 6

The values for the SGVP per unit of irrigation water show rising line, following the general trend of increasing agricultural production over the last decade . Despite the rising trend, there is a lot of variation between the years, the lowest value being 0.31 US$ per cubic meter irrigation supplied and the highest 1.24 US$ per m^3. A closer analysis based on seasonal instead of annual values, reveals a rather high correlation[7] between SGVP per unit of irrigation and precipitation (refer figure 6). If the precipitation is high, less irrigation will be needed (and hence applied). Therefore, in wet years the indicator gives high values, in dry years low values. The strong correlation between precipitation and the amount of irrigation supplied reflects a very efficient use of rain in the Samaca Irrigation Scheme. The command area is small and compact and if it rains the valve operator at the main reservoir will close the gate. Farmers who still need water can use water from their individual storage tanks at their field.

Compared with other schemes throughout the world Samaca Irrigation Scheme has one of the highest SGVP per unit of irrigation water applied. This is due to the combination of a reasonable amount of rainfall spread over the year, the relative low values of evapotranspiration due to climatic factors and the ability of farmers to use rain effectively for their crops.

Water consumption by crop ET is used in the calculation of SGVP per unit of water consumed (Molden et al. 1997). Potential ET is used to approximate actual ET due to lack of information on crop water stress. Water can also be consumed by flow to sinks and other non-crop ET (Seckler 1996). In the case of Samaca crop ET will be the dominating factor in overall water consumption. as there is little flow to deep sinks due to the hilly nature of the area. Free water surface evaporation losses from both reservoirs will be limited due to low temperatures at the altitude of 3500 m. Water that is not consumed locally is available for use for down stream users. In fact, drainage water leaving the command area is used for a small irrigation scheme further down stream. The SGVP per unit of water consumed varying from 0.31 US$ to 0.77 US$ per m^3 is considerably lower than the SGVP per unit of irrigation applied (0.31 - 1.24 US$ per m^3). An important part (average of 45 % over 11 year) of the crop water requirements is met by precipitation. The increase of irrigated pasture (low value and water consuming) causes a drop in 1991 but soon after the values increase again due to the growing importance of high value crops like onion and potato.

[7] correlation coefficient amounts to 0.76

3.2 *Water related indicators.*

A. Relative Water Supply and Relative Irrigation Supply

figure 7

The relative water supply was originally developed by Levine (1982) as a measure of water availability. It indicates how much water (in the form of rain and irrigation) is available in relation to the total water needs. Values lower than 1.5 suggest a 'tight' water availability in which strict management is required to meet needs in a satisfactory way[8]. It lends itself to improved understanding for the major participants in the irrigation process i.e. irrigation managers and farmers. In Samaca the values vary from 1.23 for the driest year to 2.04 for the wettest year. The low values in the drier years suggest a tight water availability. The farmers reacted on this situation by constructing small earthen reservoirs in their plot to allow them to be more flexible and independent of the system's water supply in moments of water scarcity. At present there are some 567 of such reservoirs, with an average capacity of some 3000 m^3 and the number is still growing.

The relative irrigation supply gives the fraction of the amount of irrigation actually supplied in relation with the net irrigation needs. It was calculated at both field and scheme level. For field level calculations the volumes at field inlets reported by ditch keepers are used. At field level the values are generally low, with an average of 0.88. In the dry year 1991 the computed value of 0.49 would imply that only half of the (net) irrigation requirements were met. The calculated values are probably under-estimating the actual values for RIS. An explanation could be that ditch keepers tend to under-estimate the quantity of water supplied to match reported figures with the planned quantities. Moreover, in 1990 the volumetric fee was abolished so that it became less important to measure water quantities accurately. This observation is supported by the fact that crop yields hardly suffered during this period.

The RIS at scheme level is higher due to conveyance and operational losses in the main canals. An average at scheme level of 1.61 compared to field level values reflects an conveyance and operational efficiency of around 55 %.

Roughly, the RWS and the RIS are following the same pattern. In years of water abundance the irrigation supply is relatively high while in water short years the RIS only is around 1.0. The figures show that the Samaca Irrigation Scheme is able to use the water efficiently. The high irrigation amounts in water abundant years does not mean that the water is wasted or lost because downstream the system's drainage water is reused by another irrigation scheme.

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[8] Levine (1982) suggest this critical value of 1.5 for rice systems in Asia. Most probably for non-rice systems like Samaca this value will be higher because of lower field application efficiencies.

The changes in irrigation management are not clearly reflected in RWS and RIS. Total precipitation appeared to be a far more predominant factor determining values of these indicators than agricultural and water management practices.

B. Water Delivery Capacity

figure 8

The water delivery capacity indicates the degree in which the actual canal capacity is sufficient to convey the peak demand of the overall system. At the same time it gives an indication of the degree in which the system is utilized in comparison with its actual full capacity. Until 1989 the values fluctuated around 4, indicating a degree of under-utilization of the infrastructure's full capacity by a factor 4. Then it suddenly drops down to 1.0 in 1992 while in the last four years it stabilized around 1.7. This sudden change can be attributed to the changes in cropping pattern as described in chapter 2. The introduction of onion as cash crop causes an increase in water requirements because onion demands more water than crops previously prevailing in the system (like barley). The augmentation of area under irrigated pasture further increases crop water requirements, mainly because of the length of the growing season. The low values of the water delivery capacity in 1992 are caused by the low precipitation (and hence high irrigation demands) combined with a sudden increase in area irrigated pasture.

From the temporal variation in the water related indicators an impact of Irrigation Management Transfer on water management could not be deduced. Most probably there were no major changes in water management after transfer because the WUA continued following the same procedures for water distribution as the government agency was applying before transfer. Furthermore there were no significant changes in infrastructure after 1993.

3.3 Financial indicators

A. Financial self-sufficiency and fee collection rate

figure 9

From 1986 to 1990 the financial self-sufficiency of the scheme was average 35 %, indicating that only 35 % of the total operation and maintenance expenditures were paid out of the collection of water fees and 65 % was subsidized by the government. With the Irrigation Management Transfer this situation altered dramatically. Although the actual transfer took place at the end of 1992, the government already started the process in late

1991 by increasing the water fees. The water fees were raised with a 170 % from approximately 19 to 42 US$ per hectare[9] (refer table 4) and financial self-sufficiency rose from 50 % in 1991 to 109 % in the next year, indicating that by that time the government subsidies were reduced to zero and all cost to run and maintain the system were covered by the users themselves. Since IMT the system has not received any government subsidies except for some financial support for maintenance of local dirt roads.

However, a closer look at the financial situation of the scheme reveals a less optimistic picture and three issues might negatively influence the financial self-sufficiency in the near future. Firstly, although the system has been able to pay its operation & maintenance expenditures out of the water fee payments, it has no provision for an emergency and/or revolving fund. This situation is common in the transferred systems in Colombia (Quintero, 1997) and provokes the question who will pay for rehabilitation if this becomes necessary in the near future.

Secondly, for 1997 the WUA requested the government support to rehabilitate the main canal. The government approved rehabilitation works for some 140,000 US dollar to be spent in the first trimester. The execution and the payment of the works will be done under direct management of the government agency. This expenditure will not be visible in the administration of the scheme. Therefore, the financial self-sufficiency will remain roughly at the same level on paper, while in reality the government started subsidizing the system's rehabilitation.

A third concern is the decline in fee collection rate over the last few years. The fee collection rate was at its highest (85 %) just before transfer, probably because the irrigation agency at that time paid extra attention to fee collection in order to reduce subsidies. The last 4 years the collection rates are slowly declining to 70 % in 1996. The outstanding debt rose from US$ 34,000 at the time of transfer to US$ 118,000 in 1996, of which about 35 % was formed by accumulated interest. The Board of the WUA recently decided to involve lawyers to get people to pay their outstanding debts. As the water is allocated per irrigation unit it is hard to cut off water from individual farmers, although the statutes of the WUA mention this sanction in case of non-payment.

B. O&M expenditures per unit of land

graph 11

The total O&M expenditures (corrected for inflation, base year 1995) tend to increase only slightly over the years (refer table 4), although the cultivated area increased considerably over the years. The total O&M expenditures appeared to be independent from the area cultivated. This situation is inherent at the way the water fees and the O&M budgets are fixed: since the management transfer the fees are raised each year according

[9] this is the highest water fee category valid for valley. In the hills the fee is 55 % lower

to the inflation. The O&M budgets are then determined according to amount of money they are expecting to collect from the water fees. So, the water fees and O&M budgets are not based on the maintenance needs but on anticipated water fee collection. According to the order of priority works are executed as far as the money lasts. Emergencies like machines breaking down lead to the postponement of other works. Apparently the WUA is not able to convince farmers that a raise in water fee in real terms might be needed to do all necessary maintenance. The way in which the maintenance is planned -- based on the amount of water fees farmers are prepared to pay rather than on real needs -- may cause a deterioration of the infrastructure and equipment in the long run, although from the indicators there is little evidence that this is already the case.

The O&M costs per hectare of the command area remain more or less on the same level, fluctuating around 35 US dollar per hectare. Due to the increased irrigation intensity expenditures per cultivated area steadily come down from 185 US dollar per hectare in 1986 to 75 US dollar in 1996. The sudden peak in 1994 is caused by the exceptional high expenses that year due to some emergencies like machine break down.

The irrigation management transfer did not have visible impacts on the total O&M expenditures. However, a closer analysis of the financial data reveals a shift in money spent: after transfer the WUA started to cut down on costs of personnel involved in operation. This results in less ditch keepers and a higher personnel turnover. This might endanger the smooth operation of the system in the long run although from the indicators there is little evidence that this is already the case.

C. O&M expenditures per unit of water

O&M expenditures in Samaca Irrigation System are independent of the total amount of water applied. Consequently, the O&M expenditures fluctuates with the amount of irrigation water applied which, as mentioned earlier, highly correlates with the amount of rainfall. The average O&M expenditures per unit of irrigation applied over the last decade amounts to US$ 0.011 per m^3. So, only 2 to 3 % of the SGVP per cubic meter of irrigation applied is spent on O&M.

There were no data available to compare these figures with other schemes.

D. Gross return on investment

The construction of the Samaca Irrigation Scheme started in 1941 when the biggest of the two reservoirs was built. Since then the system was many times adapted and improved. The last big improvement was the construction of the second reservoir in 1992. Because of the large time lapse in which the system evolved to its actual form, it is hardly possible to give an estimate of the total construction costs. Therefore, the mean investment cost per hectare of a nearby system currently under construction is taken as basis for the calculation of the gross return on investment. This investment amount to about 7000 US$ per hectare, bringing the return on investment on 22 %. The investment cost of 7000 US$ per hectare is probably an over-estimation for the Samaca Irrigation Scheme because the nearby scheme uses a more expensive irrigation technology.

Data to establish a temporal analysis over the last decade were not available.

4. Summary and concluding remarks

This case study showed that the minimum set of indicators, when applied over a range of years provides a very suitable tool to describe trends and changes in the Samaca Irrigation System. With basic data on climate, cropping pattern, yields, prices, irrigation and O&M expenditures a temporal analysis of performance could be made. Furthermore, a comparative performance evaluation in Samaca in relation to other schemes around the world could be established. In view of the simple calculation method and basic data requirements the minimum set of indicators could be very well applied to other schemes to study developments in performance over time.

Trends and changes reflected by the performance indicators

The abolishment of the volumetric fee in 1990 led to a sharp increase in irrigated pasture at former fallow land areas. Apparently farmers decided the convert fallow land in a low labor intensive, low value but water consuming culture like irrigated pasture when the water charges became independent of the volume of water used. As a result the irrigation intensity and the overall productivity per unit of the command area augmented while the productivity per unit of water consumed showed a decline. Later the area cultivated with cash crops like onion and potato gained importance at the cost of irrigated pasture and standardized gross value of production per unit of both land and water increased. At the same time the water delivery capacity came down indicating a growing intensive use of the system's physical infrastructure. Remarkably, this increased intensive use does not seem to have impacts on the total O&M expenditures which only increases slightly over the years. The O&M expenditures per hectare of the command area decline because an increasing part of the command area is being cultivated.

The correlation between precipitation and output per unit of irrigation reveals an efficient use of rain. This is due to the compact character of the command area and the numerous little reservoirs constructed by individual farmers to be more flexible and independent of the system's water distribution. This fact is also reflected in the relation between relative water supply and relative irrigation supply which broadly follow the same patterns.

The impacts of Irrigation Management Transfer are mainly found in the financial management of the scheme. The financial self-sufficiency -- still around 35 % in the late 80s -- is more than 100 % during the last few years, indicating that the beneficiaries bear the full O&M costs of the system by paying water fees. Although farmers are able to operate the system with the collected water fees, they do not have an emergency or revolving fund. The question remains who will pay for emergencies or rehabilitation when this becomes necessary in future. For this year (1997) the WUA requested the government for assistance for rehabilitation works in two canals.

There is no indication that after management transfer the WUA is able to run the system at lower costs than the government agency. The total O&M expenditures before and after IMT remained more or less on the same level. This is mainly due to the way in which budgets are fixed. The water fees are based on previous fees adapted for inflation. Maintenance works are based on the amount of money the WUA is expecting to collect rather than real needs. The actual (low) spending on maintenance might result in a deterioration of the infrastructure on the long run although from the indicators there is no evidence that this is already the case.

To obtain a better judgment of the impacts of irrigation management transfer a more detailed analysis is essential since these are mainly found in the financial and personnel management of the system, rather than on outputs of the system. In this study the indicators O&M expenditures per unit of land and water and fee collection rate were added to achieve a better understanding of the IMT process..

Performance evaluation relative to other schemes

Compared to 18 schemes where the set of performance indicators was applied the Samaca Irrigation Scheme ranks among the highest 25 % in production per unit of land and unit of water. The SGVP per unit of land is high because of the high value cash crops grown in the command area (onion and potato) while the major part of the other schemes paddy is grown. The high SGVP per unit of irrigation applied is due to the reasonable amount of rainfall relative to the reference ET and the farmers' ability to utilize this rain effectively. Comparing the values of the Relative Water Supply among the range of systems, Samaca has an average amount of water available in relation to its water requirement while the Relative Irrigation Supply ranks among the lower 25 % indicating an efficient use of irrigation water.

Limitations of the minimum set of indicators

Application of the minimum set of indicators provides a good overview on how the scheme as a whole performs relative to other schemes or compared with foregoing years, making use of basic information which often is available on scheme level. However, the applied indicators do not lend themselves to a thorough in-depth cause and effect analysis of the observed performance variation. In this study in order to clarify certain performance features additional indicators, like fee collection rate and O&M expenditures were introduced and at a few occasions seasonal instead of annual analysis was necessary for better understanding. To evaluate and fully comprehend the impacts of the irrigation management transfer additional indicators focused on internal management processes (and hence extra information) will be essential. In this case study the entire scheme was taken as unit of analysis without paying attention to aspects like equity of distribution, timeliness and reliability of flow rates. By leaving out these internal processes at local level, the analysis might be more interesting for researchers and policy makers than for farmers and system managers. For example the indicators express agricultural outputs in gross values while for farmers the net values or profitability are of principal concern.

The quality of the indicators is as good as the data utilized to compute them. In this study historical data derived from secondary sources are used. Despite careful cross checking some distortion could not be avoided. Irrigation water quantities at field level might be underestimated by ditch keepers while agricultural yields are likely to be appraised at the high side by agricultural extension workers. These uncertainties are inherent to data from secondary sources.

The amount of water consumed by crops, water lost by non-beneficial evaporation and irrigation needs cannot be measured directly in the field but must be approximated using existing formulas and/or the researchers' assessments. The consistent use of adequate methods to estimate effective rainfall, crop water requirements and irrigation needs is a prerequisite for cross system comparison.

The minimum set does not include indicators concerning environmental issues or sustainability. A wide range of indicators is available for example the percentage of the command area abandoned due to environmental problems (salinity, water logging, erosion) or quality of water entering the system related to the quality of water leaving the command area. For example in Samaca it would have been interesting to evaluate the effects of the augmentation of the area cropped with onion on water quality since a large amount of agro-chemicals are used for this crop[10]. This would have given a more balanced view of the system's sustainability than only looking to productivity. The main obstacle is the availability of information due to the bias of data collectors towards agricultural information and water quantities rather than environmental data like water quality.

[10] In fact, in Samaca an environmental study was conducted in 1996 (Gonima and Gomez, 1996). The study concluded that there were no water quality problems in the system. As samples were only taken during a short period of time no longer term conclusions about sustainability issues could be drawn.

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Table 1: Climate data
Samaca Irrigation Scheme

Yearly values

Year	total precipitation (mm)	ETo (Penman) mm *	av. daily temp. (°C)
1986	781.3	976	13.7
1987	565.6	1033	14.2
1988	891.1	965	14.3
1989	610.1	976	13.4
1990	691.0	1011	14.0
1991	553.3	1026	14.3
1992	647.6	1033	14.4
1993	573.6	1030	14.3
1994	803.7	976	14.1
1995	699.2	1051	14.3
1996	758.7	972	13.7
Averag	688.7	1004.5	14.1
St Dev	110.6	31.6	0.3

Mean monthly values

Month	Total precipitation (mm)	Effective rain USDA (mm)	ET_o Penman Monteith (mm)	ET_o - Eff. Rain (mm)	Standard deviation total prec.	Standard deviation ET_o
Jan	26.0	23.7	5.2	18.4	23.2	5.2
Feb	53.6	46.2	7.8	38.4	30.1	7.8
Mar	83.2	65.1	6.1	59.0	48.6	6.1
Apr	69.5	58.4	6.0	52.5	28.0	6.0
May	66.0	55.9	3.7	52.2	27.6	3.7
Jun	38.4	34.7	3.8	31.0	19.7	3.8
Jul	35.1	32.4	4.5	27.9	11.7	4.5
Aug	27.6	25.9	5.5	20.4	9.9	5.5
Sep	49.0	42.1	6.7	35.4	31.7	6.7
Oct	94.4	69.7	7.1	62.5	61.5	7.1
Nov	109.2	79.9	4.3	75.6	54.8	4.3
Dec	36.8	32.5	6.4	26.1	29.2	6.4
Annual	688.6	566.4	67.0	499.5	27.3	1.3

* calculated with CROPWAT using the modified Penman Monteith formula

Table 2: Agricultural Indicators Samaca Irrigation Scheme

Year	Irrigation intensity ratio	SGVP per unit command area (US dollar per ha)	SGVP per unit cultivated area (US dollar per ha)	SGVP per unit irrigation supplied (US dollar per m^3)	SGVP per unit of water consumed (US dollar per m^3)
1986	0.82	889	1328	0.31	0.33
1987	0.80	1027	1272	0.39	0.33
1988	0.72	1304	1665	0.59	0.47
1989	0.65	1287	1745	0.36	0.45
1990	1.00	1450	1358	0.42	0.32
1991	1.63	2276	1344	0.44	0.31
1992	1.62	2521	1436	0.65	0.32
1993	1.64	2462	1471	0.63	0.34
1994	1.45	2592	1799	1.05	0.44
1995	1.49	4042	2788	1.02	0.71
1996	1.51	4373	2976	1.24	0.77

0.44

all prices mentioned are corrected for inflation with base year 1995

Table 3: Water Related Indicators Samaca Irrigation Scheme

Year	Relative Water Supply (ratio)	Relative Irrigation Supply scheme (ratio)	Relative Irrigation Supply field * (ratio)	Water Delivery Capacity (ratio)
1986	1.52	1.47	0.89	4.35
1987	1.55	1.62	0.90	2.97
1988	2.03	2.14	0.92	3.44
1989	2.04	2.63	1.19	4.52
1990	1.60	1.90	0.98	1.73
1991	1.36	1.30	0.49	1.23
1992	1.25	0.98	0.57	1.01
1993	1.23	1.13	0.60	1.67
1994	1.40	1.19	0.96	1.83
1995	1.60	1.82	1.30	1.71
1996	1.61	1.55	0.88	1.71
Average	1.56	1.61	0.88	2.38
StDev	0.27	0.49	0.25	1.24

* based on volumes at field inlets reported by ditch keepers

Table 4: Financial Data
Samaca Irrigation Project

Year	Fee collection rate (%)	Financial Self-sufficiency (%)	Fixed water fee (valley) (US dollar per ha)	Total O & M expenditures (US dollar)	O & M expenditures per unit command (US dollar per ha)	O & M expenditures per unit irrigation (US dollar per m^3)
1986	74	23	9	82,916	38	0.013
1987	78	23	9	83,427	37	0.014
1988	55	31	9	94,909	40	0.019
1989	48	29	9	94,563	36	0.010
1990	83	50	18	97,976	35	0.010
1991	85	47	19	104,053	36	0.007
1992	76	109	42	82,052	28	0.007
1993	81	152	37	64,213	22	0.006
1994	77	79	41	119,609	41	0.017
1995	71	107	45	94,520	32	0.008
1996	70	102	45	94,556	32	0.009

0.011

Figure 2: Changes in cropping pattern Samaca Irrigation Scheme

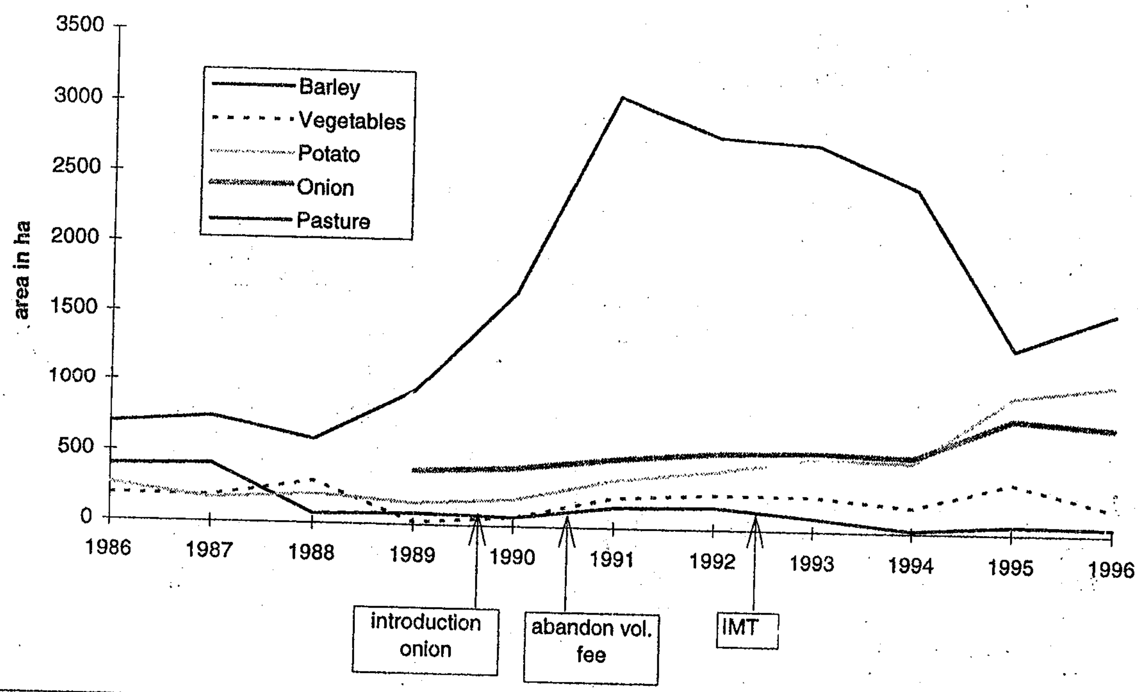


Figure 3: Irrigation intensity Samaca Irrigation Scheme

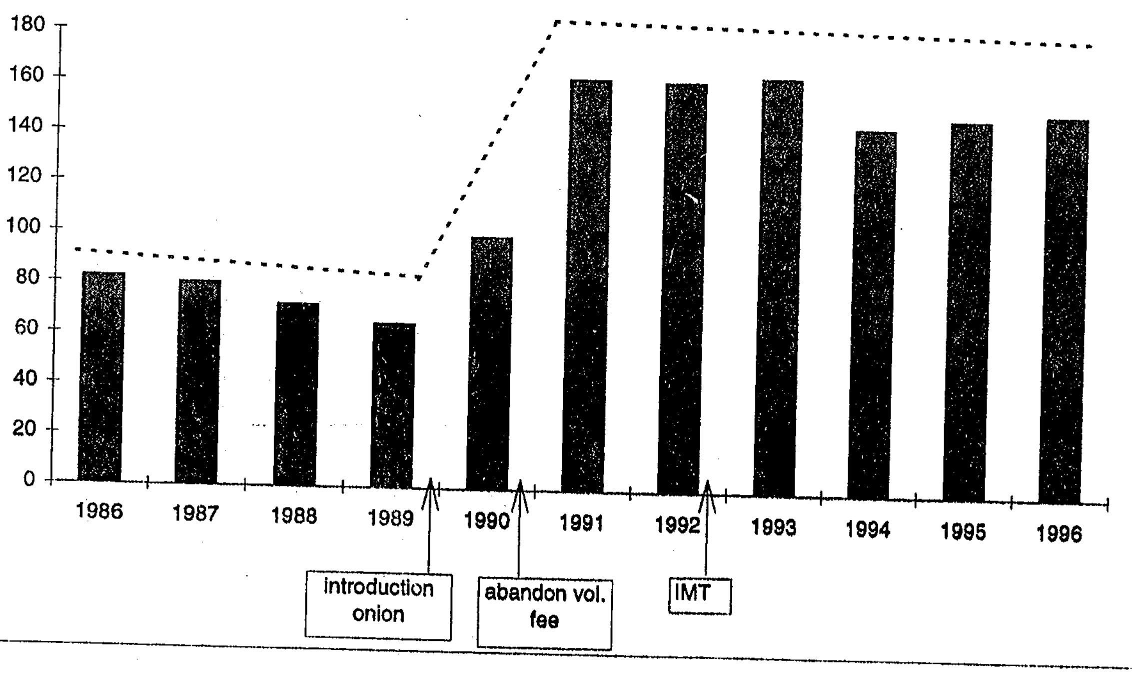


Figure 4: Standard Gross Value of Production per unit of land Samaca Irrigation Scheme

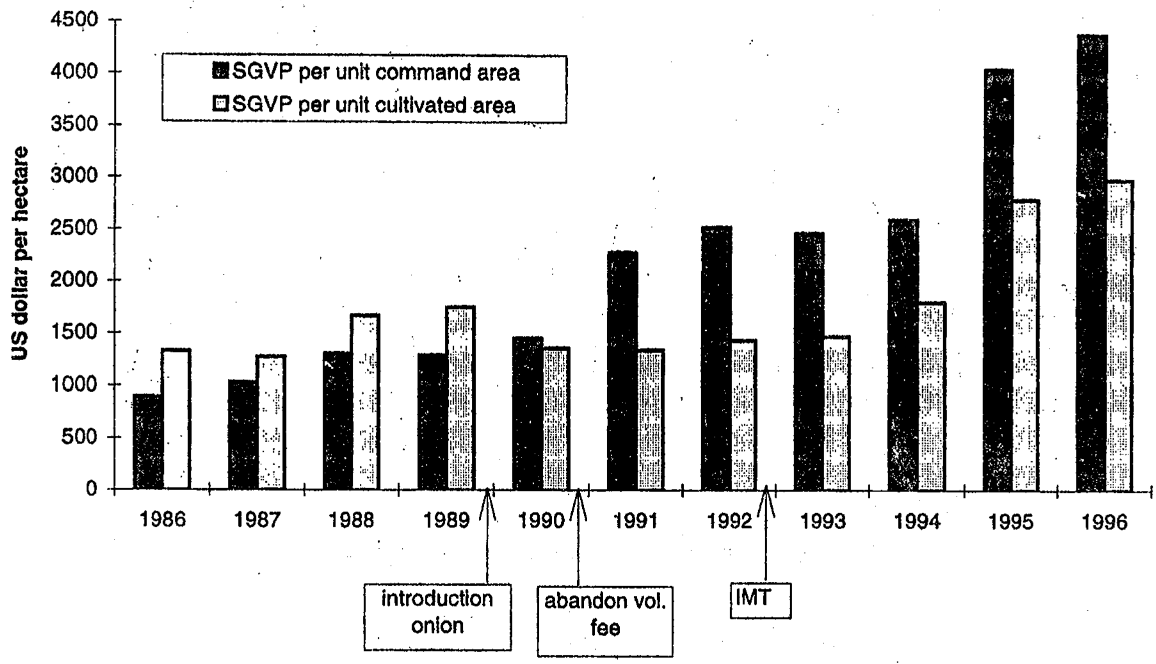
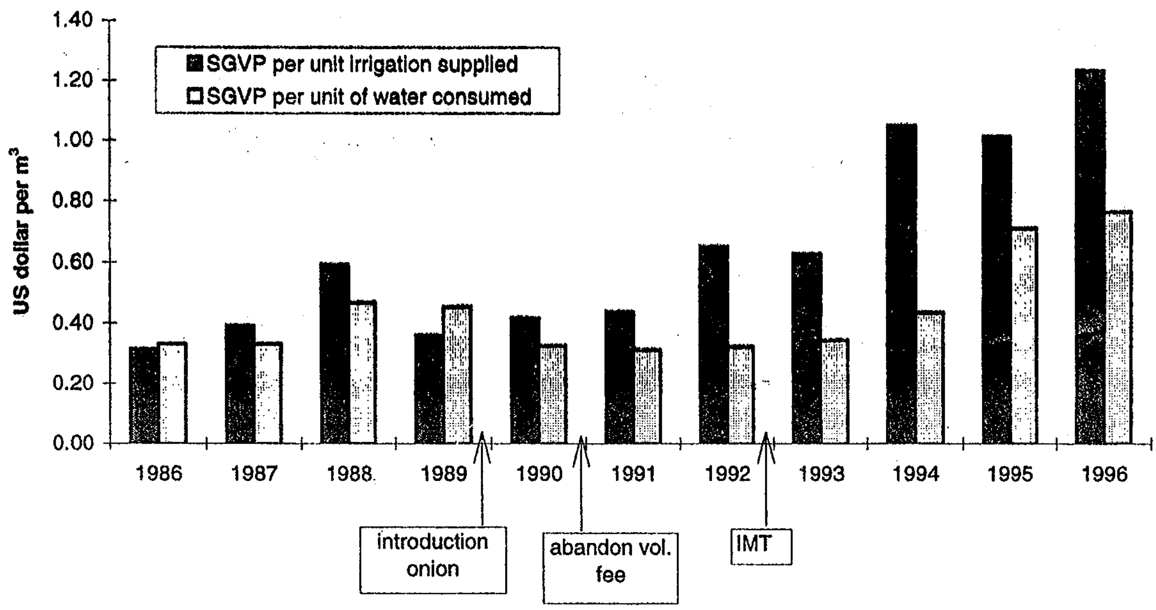


Figure 5: Standard Gross Value of Production per unit of water Samaca Irrigation Scheme



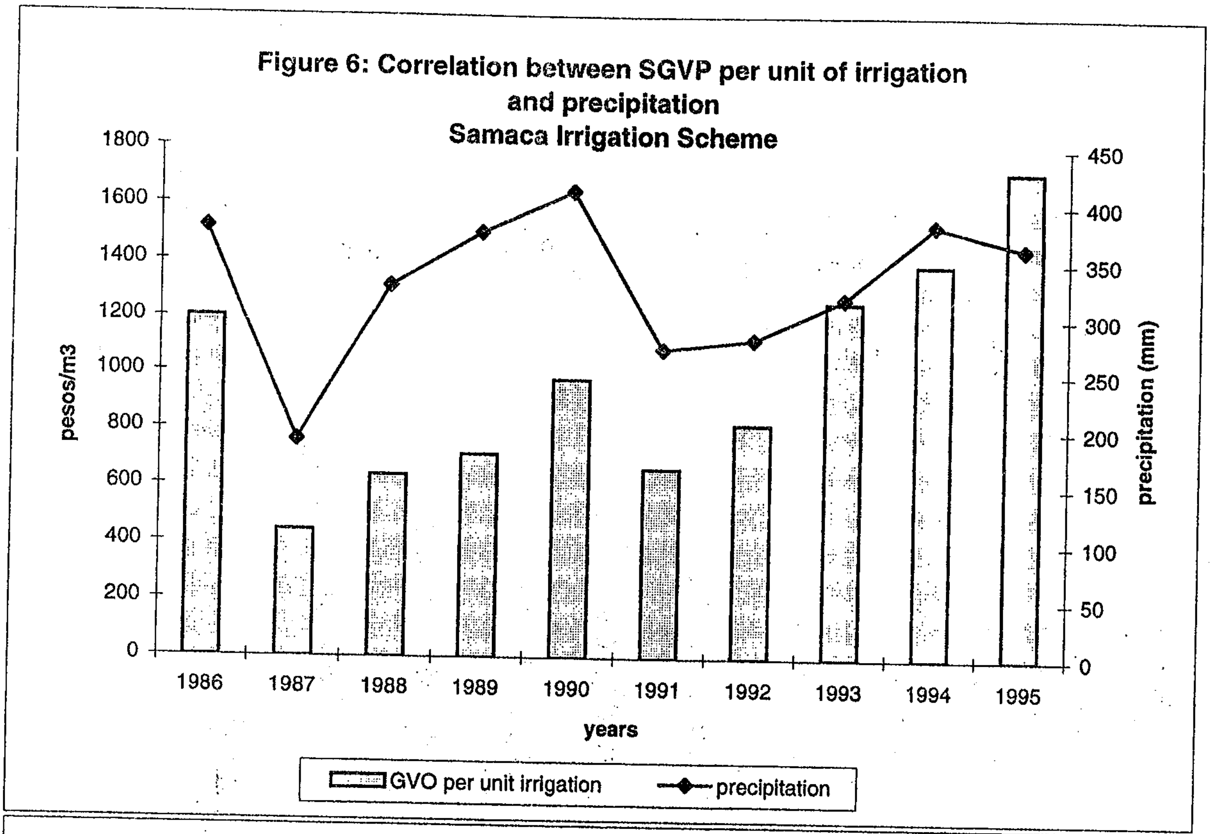


Figure 6: Correlation between SGVP per unit of irrigation and precipitation
Samaca Irrigation Scheme
pesos/m3
1800
1600
1400
1200
1000
800
600
400
200
0
precipitation (mm)
450
400
350
300
250
200
150
100
50
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
years
GVO per unit irrigation
precipitation

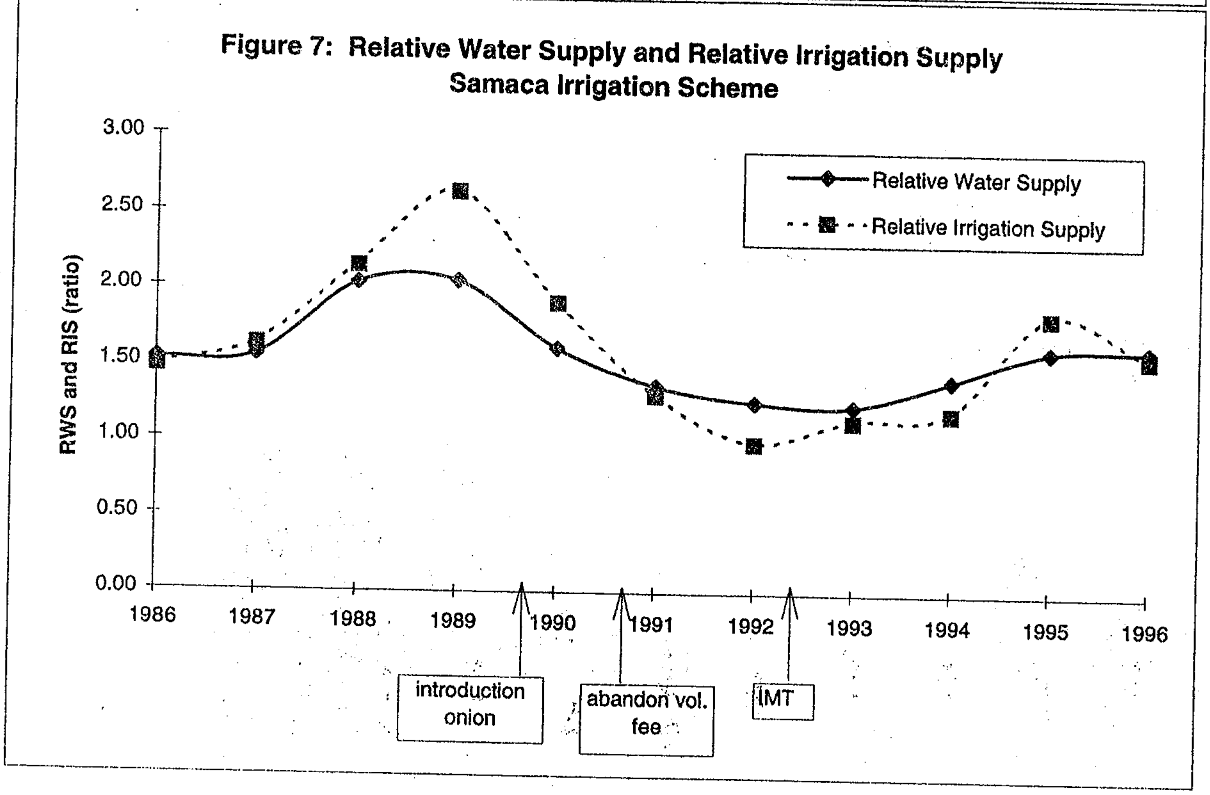


Figure 7: Relative Water Supply and Relative Irrigation Supply
Samaca Irrigation Scheme
RWS and RIS (ratio)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Relative Water Supply
Relative Irrigation Supply
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
introduction onion
abandon vol. fee
IMT

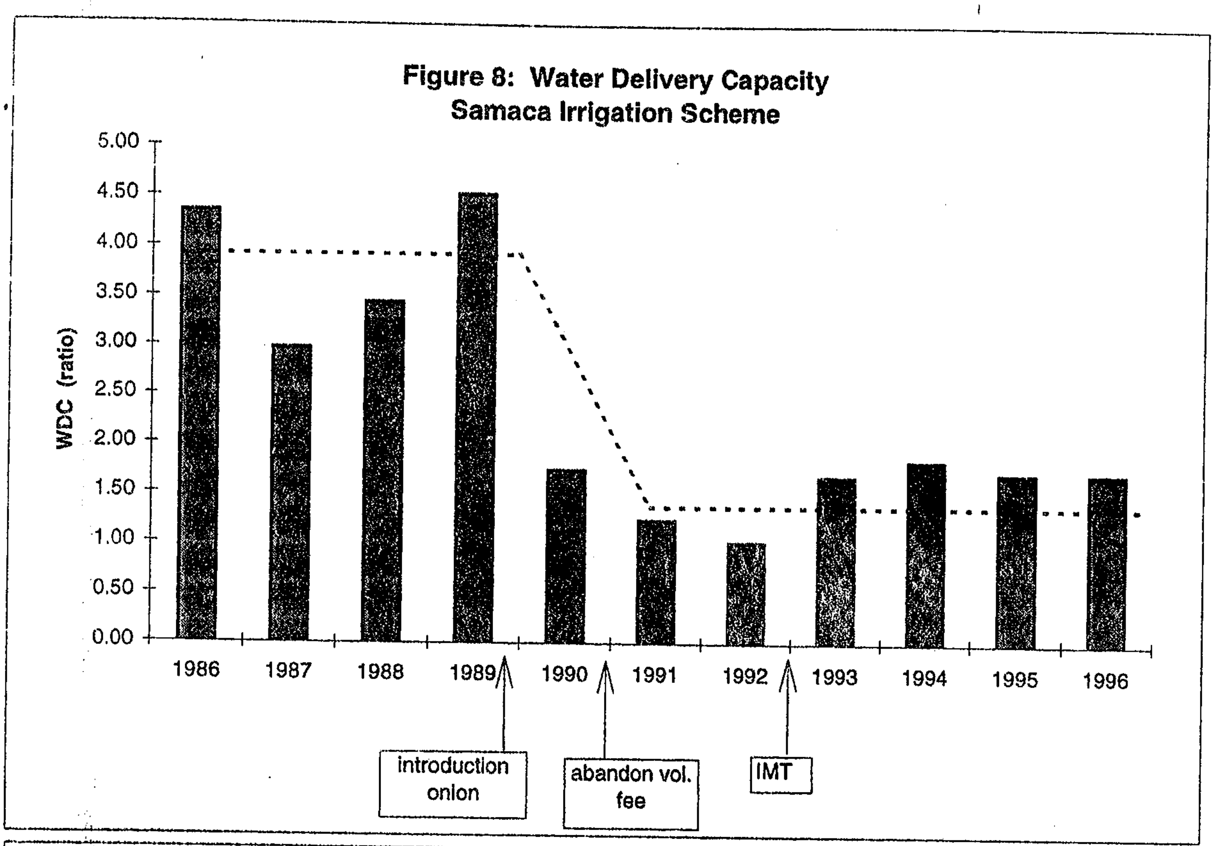


Figure 8: Water Delivery Capacity Samaca Irrigation Scheme

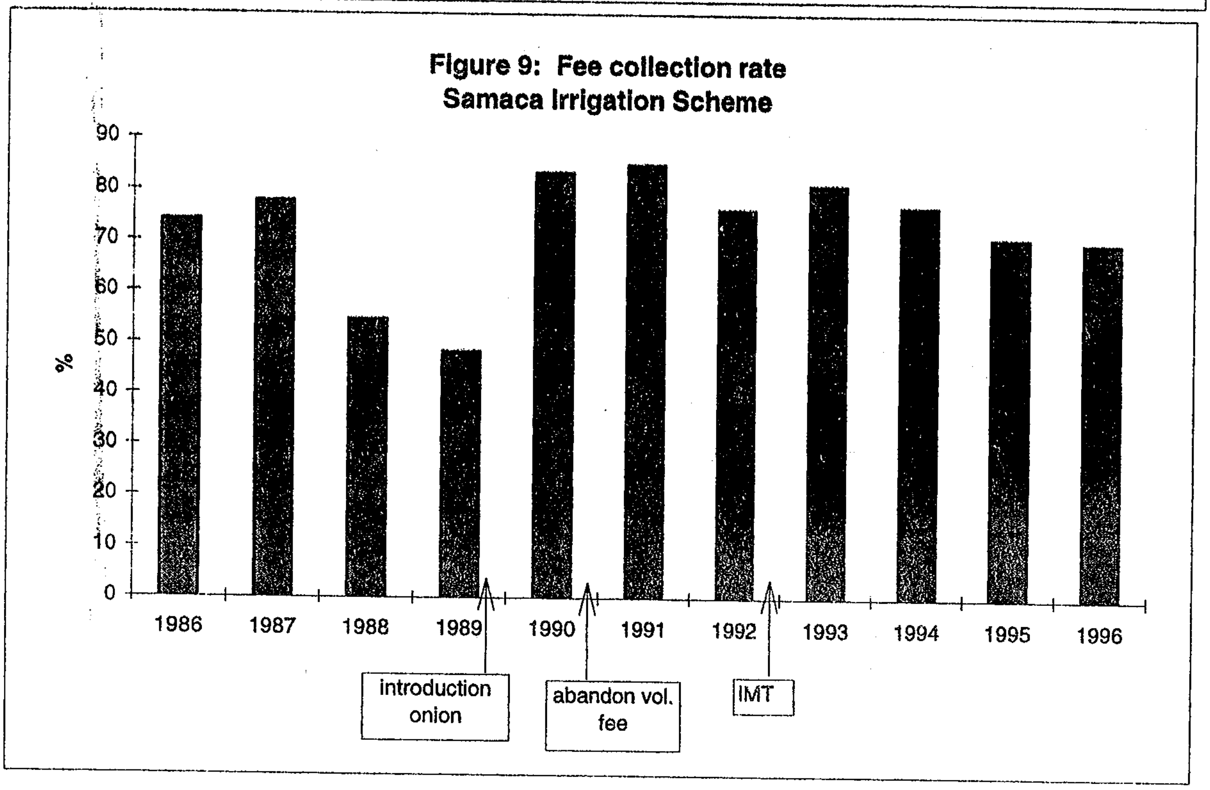


Figure 9: Fee collection rate Samaca Irrigation Scheme

Figure 10: Water Fee and Financial Self-sufficiency
Samaca Irrigation Scheme

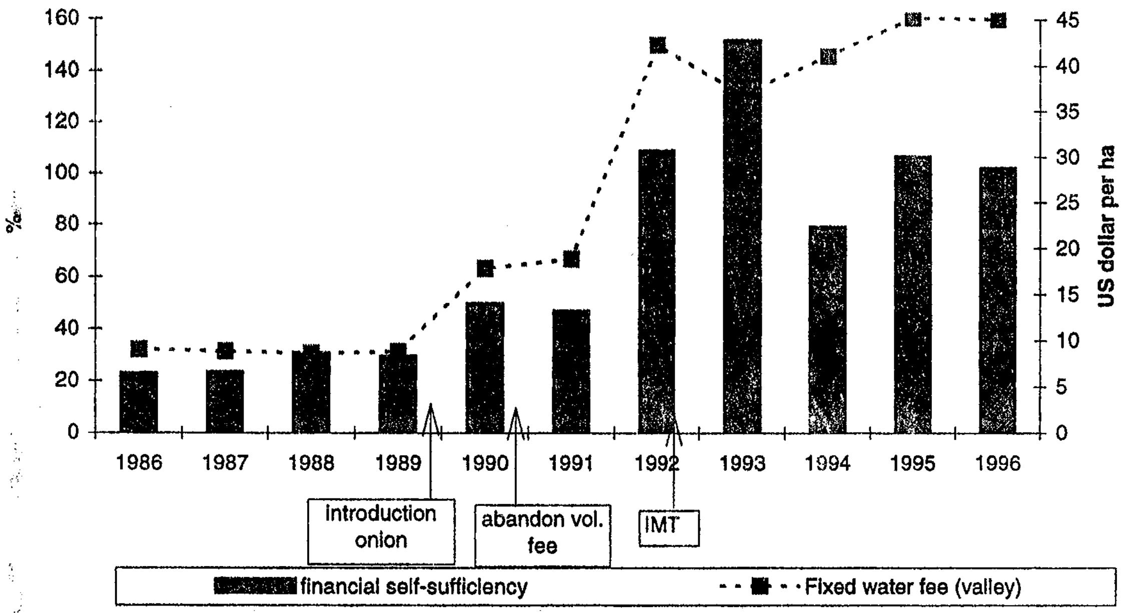
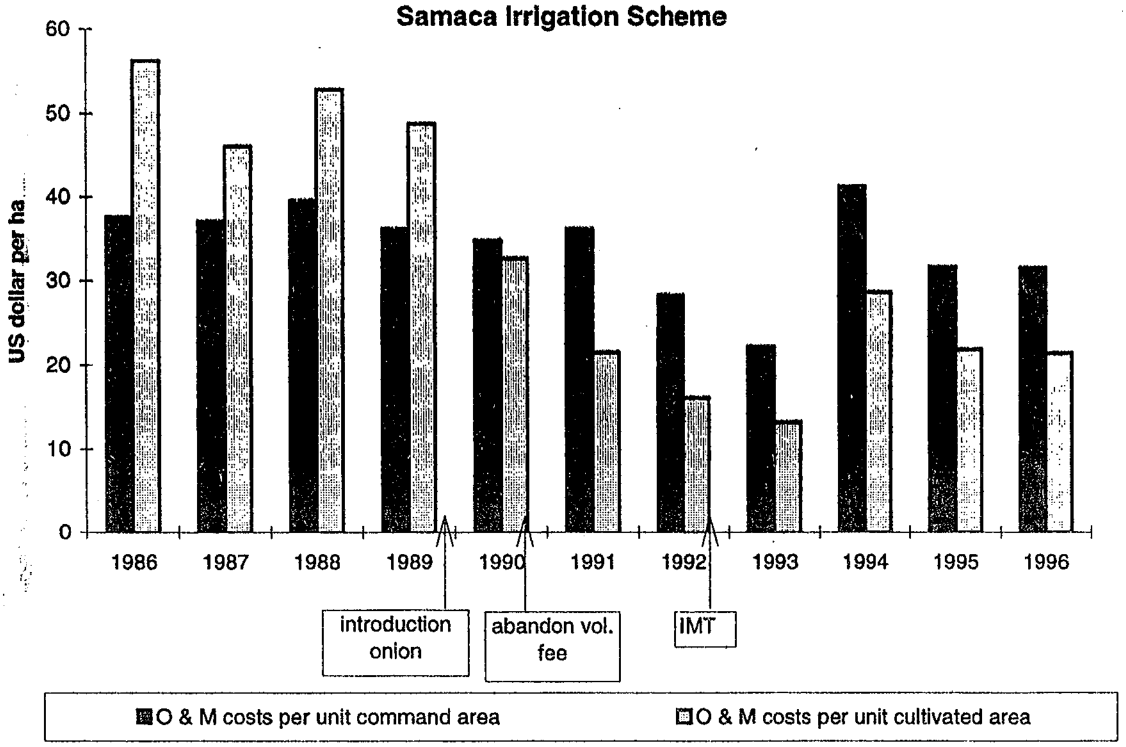


Figure 11: O & M expenditures per unit of land
Samaca Irrigation Scheme



ANNEX 1: Definition of Performance Indicators Used

Agricultural Indicators

1. $\text{Irrigation Intensity (\%)} = \dfrac{\text{Irrigated Cropped Area } (A_{cropped})}{\text{Command area } (A_{net})}$

2. $\text{Output per cropped area } (\dfrac{\$}{ha}) = \dfrac{\text{Production}}{\text{Irrigated Cropped Area } (A_{cropped})}$

3. $\text{Output per unit command } (\dfrac{\$}{ha}) = \dfrac{\text{Production}}{\text{Command area } (A_{net})}$

4. $\text{Output per unit Irrigation Supply } (\dfrac{\$}{m^3}) = \dfrac{\text{Production}}{\text{Diverted Irrigation Supply } (V_{div})}$

5. $\text{Output per unit Water Consumed } (\dfrac{\$}{m^3}) = \dfrac{\text{Production}}{\text{Volume of Water Consumed by ET } (V_{consumed})}$

where,

Production is the output of the irrigated area in terms of gross value of production measured at world market prices (see below),
Irrigated Cropped Area is the sum of the areas under crops during the time period of analysis,
Command Area is the nominal or design area to be irrigated[1],
Diverted Irrigation Supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater, and
Volume of Water Consumed by Crops is the evapotranspiration of crops.

The production is estimated by using the concept standardized production. (refer to Perry 1996 and Molden 1997 for details) computed as follows:

$$SGVP = \left(\sum_{crops} AiYi\frac{Pi}{Pb}\right)Pworld\,,$$

[1] For example, consider an irrigated area that nominally is to serve 1,000 ha. During the rainy season, 800 ha are irrigated, and during the dry season, 400 ha are irrigated. In this case, the irrigated cropped area is 1,200 ha. The command area is 1,000 ha.

where,

SGVP is the standardized gross value of production,
Yi is the yield of crop i,
Pi is the long term average of the local price of crop i, and
Pworld is the long term average of the value of the base crop traded at world prices.
Ai is the area cropped with crop i
Pb is the long term average of the local price of the base crop

Water related indicators

6. Relative Water Supply $= \dfrac{\text{Total Water Supply}}{\text{Crop Demand}}$

7. Relative Irrigation Supply $= \dfrac{\text{Irrigation Supply}}{\text{Irrigation Demand}}$

8. Water Delivery Capacity (%) $= \dfrac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}}$

where

Crop Demand = Potential crop ET, or the ET under well watered conditions.
Total Water Supply = Surface diversions plus net groundwater water draft plus rainfall
Irrigation Supply = only the surface diversions and net groundwater draft for irrigation
Irrigation Demand = the crop ET less effective rainfall.
Capacity to deliver water at the system head = the present discharge capacity of the canal at the system head, and
Peak Consumptive Demand is the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

Financial Indicators

9. Financial Self Sufficiency (%) $= \dfrac{\text{Revenue from Irrigation}}{\text{Total O\&M Expenditures}}$

10. Fee Collection Rate (%) $= \dfrac{\text{Collected Fees}}{\text{Anticipated Fee collection}}$

11. Gross Return on Investment (%) $= \dfrac{SGVP}{\text{Cost of Irrigation Infrastructure}}$

12. O & M expenditures per unit of land $= \dfrac{\text{Total O\&M Expenditures}}{\text{Command area } (A_{net})}$

13. O & M expenditures per unit of water $= \dfrac{\text{Total O\&M Expenditures}}{\text{Diverted Irrigation Supply } (V_{div})}$

where:

Cost of Irrigation Infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the SGVP,

Collected fees, is the annual revenue generated from water and irrigation fees, paid by water users, excluding income from anterior debt payment or interest,

Anticipated Fee Collection, is the expected annual revenue generated from water and irrigation fees, as billed to water users, excluding anterior debts or interest,

Revenue from Irrigation, is the revenue generated, either from fees, or other locally generated income, but excluding revenues from government subsidies,

Total O&M Expenditures is the amount expended locally through O&M plus outside subsidies from the government.

ANNEX 2: Calculation example performance indicators, Samaca Irrigation Scheme, Colombia, 1995

A. Standardized Gross Value of Production

For each season the 6 main tradable crops and irrigated pasture were taken into account. These crops cover more than 95 % of the cultivated area.
For example in 1995 the following data were collected:

	season A (Jan - Jun)					season B (Jul - Dec)				
crop	area (ha)	yield (ton/ha)	price (pesos / kg)	ave-rage price	GVO (million pesos)	area (ha)	yield (ton/ha)	price (pesos / kg)	ave-rage price	GVO (million pesos)
potato	498	25.0	265	221	***3299***	475	18.0	171	200	***1462***
maize	95	1.3	502	380	***62***	80	2.0	250	346	***40***
vegetable	145	20.0	189	255	***548***	216	20.0	194	239	***838***
peas	349	4.0	1259	978	***1758***	270	4.0	762	889	***823***
onion	357	25.0	488	444	***4355***	455	25.0	502	467	***5710***
wheat	33	5.0	200	275	***33***	43	5.2	200	284	***45***
pasture	655	332*		332	***217***	655	332*		332	***217***
total	2132				***10,239***	2194				***9,135***

* 332,000 pesos per season per ha, four cuttings per season

SGVP = {(yield $_{crop\ 1}$) * (price $_{crop\ 1}$ / price $_{base\ crop}$) * (area $_{crop\ 1}$) +
+ (yield $_{crop\ 2}$) * (price $_{crop\ 2}$ / price $_{base\ crop}$) * (area $_{crop\ 2}$)
+ (yield $_{crop\ 3}$) * (price $_{crop\ 3}$ / price $_{base\ crop}$) * (area $_{crop\ 3}$) etc. } * (world market price) $_{base\ crop}$

Base crop is the main tradable crop cultivated in the command area. For Samaca potato is taken. To eliminate distortions due to price fluctuations, for local as well as for international prices averages are used: firstly local prices per crop and per year are corrected for inflation (base year 1995), then the 10 year average over 1986 - 1995 is taken. The average world market price for wheat is 149.4 dollar / ton.

For first season in 1995 the total SGVP is:
{25 * 498 + 1.3 * (380 / 221) * 95 + 20 * (255 / 221) * 145 + 4 * (978 / 221) * 349 + 25 * (444 / 221) * 357 + 5 * (275 / 221) * 33 + 655 * (332000 / 221)} * 149 = 6,171,168 US dollar
Likewise for second season in 1995 the SGVP is 5,899,910 US dollar
Total yearly value: ***12,071,078*** US dollar
Total command area is 3,000 hectares. Total amount of water derived (scheme level): yearly 11,867 * 10^3 m^3

GVO per unit cultivated area: (12,071,078) / (2132+2194) = ***2,790*** US dollar per ha.
GVO per unit command area: 12,071,078 / 3000 = ***4,024*** US dollar per ha.
GVO per unit irrigation delivered: 12,071,078 / 11,867,000 = ***1.02*** US dollar per m^3.

B. Crop water demand

For each crop the seasonal water demand is calculated with CROPWAT
The reference evapotranspiration (ET_o) according to Penman-Monteith and the effective rainfall are calculated with CROPWAT (option1 in main menu), seperately for each year. In this case the USBR-formula for effective rainfall is chosen. (input: daily temperature, relative humidity, windspeed, sunshine hours, total rainfall)

For example for 1995

month	average daily temp. (°C)	humidity (%)	windspeed (km/day)	daily sunshine (hrs/day)	ET_o Penman-Monteith (mm/day)	total precipitation (mm/month)	effective rainfall (USBR) mm/month
January	13.8	76	171	7.0	***3.0***	1.3	***1.3***
February	14.3	77	180	10.2	***3.7***	65.1	***56.6***
March	14.8	78	169	6.1	***3.2***	142.8	***102.0***
April	14.7	77	155	4.2	***2.8***	37.6	***34.8***
May	14.2	79	142	4.9	***2.8***	64.1	***55.9***
June	14.2	76	193	4.1	***2.7***	51.5	***46.2***
July	13.5	80	174	5.1	***2.7***	26.5	***25.1***
August	14.1	73	175	5.3	***3.0***	52.8	***47.2***
September	13.5	78	149	5.4	***2.9***	27.8	***26.3***
October	14.6	78	118	3.2	***2.5***	60.3	***53.0***
November	14.3	74	145	5.2	***2.8***	86.5	***71.5***
December	14.3	80	139	3.3	***2.3***	82.9	***69.2***
Total					***1043***	699.2	***589.1***

Then, the net crop water requirement (CWR) and the net irrigation requirement (IR) are computed for each irrigated crop and for each growing season (option 2 in CROPWAT main menu). The crop coefficients provided with CROPWAT program are used. Input: planting dates and grow length in days. For Samaca 1995 the outcomes were:

crop	area (ha)	net crop water requirement season A (mm/season)	net irrigation requirement season A (mm/season)	area (ha)	net crop water requirement season B (mm/season)	net irrigation requirement season B (mm/season)
potato	498	***394.6***	***136.7***	475	***381.0***	***118.3***
maize	95	***463.5***	***166.9***	80	***444.3***	***166.0***
vegetables	145	***351.1***	***116.2***	216	***336.7***	***138.9***
peas	349	***298.5***	***106.7***	270	***283.9***	***144.8***
onion	357	***278.6***	***94.7***	455	***270.6***	***50.1***
wheat	33	***326.3***	***137.4***	43	***329.8***	***131.3***
pasture	655	***523.8***	***245.2***	655	***511.8***	***225.5***
total	2132			2194		

The total net crop demand for season A is:

CWR_{potato} * ($area_{potato}$ / $area_{total}$) + CWR_{maize} * ($area_{maize}$ / $area_{total}$) + etc =

394.6 * (498 / 2132) + 463.5 * (95 / 2132) + 351.1 * (145 / 2132) + 298.5 * (349 / 2132) + 278.6 * (357 / 2132) + 326.3 * (33 / 2132) + 523.8 * (655 / 2132) =
387.7 mm / season

In the same way the total net irrigation requirements are computed.
Results:

season	net crop water requirement	net irrigation demand
A (Jan - Jun)	***387.7***	***158.0***
B (Jul - Dec)	***383.2***	***143.4***
Total	***770.9***	***301.4***

The ***GVO per unit consumed*** could be approximated[1] by
GVO / net CWR
in pesos: 19,374 * 10^6 / (2132 * 387.7 + 2194 * 383.2)*10 = ***1162*** pesos per m^3
in dollar: 12,071,078/ (2132 * 387.7 + 2194 * 383.2)*10 = ***0.72*** dollar per m^3
Amount of water derived:

scheme level	season A:	280.1 mm	field level	season A :	193.5 mm
	season B:	268.7 mm		season B :	198.0 mm
	yearly :	548.8 mm		yearly :	391.5 mm

Relative water supply
= (irrigation derived + total precipitation) / crop water requirements[2]
scheme level: (548.8 + 699.2) / (387.7 + 383.2) = ***1.62***
field level : (391.5 + 699.2) / (387.7 + 383.2) = ***1.41***

Relative irrigation supply = irrigation applied / irrigation requirements[3]

scheme level
548.8 / 301.4 = ***1.82***

field level
391.5 / 301.4 = ***1.30***

Water delivery capacity = actual canal capacity / scheme peak demand[4]
Actual canal capacity was measured at the main reservoir outlet. The capacity is 750 /s. The scheme irrigation requirement was calculated with CROPWAT (option 4 in main menu) using the climate data, cropping pattern, planting dates and area as mentioned above.

[1] not taken into account losses to sinks and non-beneficial ET due to lack of data
[2] net crop water requirement excluding efficiency losses
[3] net irrigation requirements excluding conveyance and application losses
[4] net peak demand excluding conveyance and application losses

For 1995 the scheme irrigation requirements are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IR in l/s/ha	0.13	0.08	0.01	0.17	0.11	0.11	0.08	0.08	0.20	0.09	0.05	0.04

Peak irrigation tequirements occur in September, 0.20 l/s/ha
Peak demand is 0.20 * cropped area = 0.20 * 2194 = 439 l/s
Water delivery capacity: 750 / 439 = ***1.71***

C. Financial data

Financial self-sufficiency = revenue from irrigation / O & M expenditures

The revenue from irrigation include all income derived from water fees, water users' association's fees, outstanding debt and interest on anterior debts payments but exclude all kind of government subsidies or payments. For 1995 this was : 92,032,056 colombian pesos. Exchange rate for 1995 is 913 pesos/dollar. Revenue = 100,802 US dollar.
O&M expenditures include all expenditures to run and maintain the system. For Samaca they include operation, maintenance and administration cost, total 86,296,340 pesos = 94,519 US dollar.
Financial self-sufficiency = (100,802 / 94,519) * 100% = ***107 %.***

Gross return on investment = gross value of output / cost of distribution system

The cost of the distribution system is not known for the Samaca Project as the system was built over a time span of several decades. As an approximation the investment cost of a similar system nearby (currently under construction) is taken. This amounted to 7000 US$ per hectare for 1996 (figures for 1995 not available). The GVO was 2976 US dollar per year per hectare of the command area.
Gross return on investment: 3096 / 7000 = ***42 %.***

ANNEX 3: Data requirements to calculate performance indicators

Climate

- monthly precipitation (in mm)
- mean daily maximum and minimum temperatures, per month (in ^{o}C)
- mean monthly windspeed (in m/s)
- mean monthly relative humidity (in %)
- mean daily hours of sunshine, per month (in hours per day)

Crops

- total command area (ha)
- cropping pattern irrigated crops (planting dates, grow lenghth in days)
- area per crop, per season or per year (ha)
- yields, per season or per year (ton/ha)
- local prices, per season or per year (local currency per ton)
- world market prices for main crop (US dollar per ton)

Irrigation

- total amount of irrigation water derived, scheme level, per season or per year (m^3)
- total amount of irrigation applied at field level, per season or per year (m^3)
- actual capacity of main canal and secondary canals (m^3/s)

Financial

- expenditures for Operation, Maintenance and Administration i.e. all cost to run the system (in local currency, per year)
- total income from water fees, farmers' contributions, outstanding debt payments etc. excluding all governement subsidies (local currency, per year)
- investment cost of irrigation infrastructure (local currency per hectare)