

Chapter 7 - Correlation Evaluation

Background

This project quantified numerous factors and indicators, but it did not actually implement any changes. There was no ability to vary one factor while keeping all other factors constant - a key requirement for many traditional statistical approaches. The research proposal acknowledged that a statistical analysis would not be valid for most of the data because of this factor, and because of the relatively small number of projects.

The previous chapters include graphs that illustrate many of relationships that were observed. Attachment C contains the values of 745 data items for each irrigation project, plus the average and coefficient of variation values. In addition, a Pearson Correlation test was run to search for meaningful data correlations. This section of the chapter describes the procedure. The remainder of the chapter presents the most pertinent results in graphical form, along with discussions of those results. The Pearson Correlation test procedure was as follows:

1. A database was developed with three types of variables:
 - Data Variables
 - ITRC and IWMI External Indicators
 - ITRC Internal Indicators
2. Mean values and the coefficient of variation (defined as the standard deviation divided by the mean) of the values were obtained. As a quality control measure, they were examined to determine if data points were reasonable or if there was some misinterpretation of the project responses.
3. A Pearson Correlation Matrix was created with the database by comparing each of the variable types to each other. This translated into a high volume of correlations to evaluate. A total of about 380 variables were put into a matrix and generated over 72,000 data pairs. A Pearson Correlation test is used to determine if there is a linear relationship between two variables. However, it does not prove cause or effect relationships.
4. Pairs of data with high Pearson Correlation Coefficients ($r > 0.7$) were identified and grouped. In other words, the "r" values of the Pearson Correlation Matrix were used indirectly - as a means of identifying interesting relationships. This reduced the evaluation to about 6,000 data pairs.
5. Further groupings were made to identify data pairs that had variables that were similar in nature. For example, there were two questions that asked about the cost of the land. One question referenced the cost of land near the head of the canal; another question asked about the cost near the end of canals. The correlation evaluation determined that both variables are highly correlated *with each other* and they were in turn correlated with same indicators. In this case, one of the data pairs was eliminated. This procedure reduced the number of data pairs to 250.

6. Data pairs that had high correlation values but clearly (through common sense) were not related to each other were eliminated from consideration. Data pairs that were based on similar calculations or were simply sub-indicators correlated to the indicator were eliminated. This filtering stage reduced the analysis to about 100 data pairs.
7. Some data pairs were expected to show a good correlation or at least interesting results but did not show up in the surviving 100 data pairs. These pairs were identified, and were added to the 100 data pairs, making a total of about 120 data pairs.
8. The data pairs were evaluated using visual inspection of scatter diagrams. Scatter diagrams were developed to examine the groupings of the projects. Additional data pairs were eliminated by inspecting the scatter plots. Some of the data had one extreme value that caused a skewing of the data. Further consolidation resulted in about 40 data pairs.
9. Table 7-1 lists the variables that had a relatively large number of high correlation values. The most interesting of the corresponding scatter diagrams were selected, and are presented in this chapter along with some discussion.
10. The results indicate that there are not strong correlations between the data variables and the external indicators. However, there was high correlation between the data variables and various internal indicators. This may indicate that the internal indicators are better suited to judge the performance of an irrigation project rather than the external indicators. For example, the external indicators can be distorted by a project that receives a high subsidy or is growing a high value crop such as tobacco. The project can be a poorly designed, mismanaged, and dysfunctional project but the external indicators might not indicate that serious changes need to be made. A feature of the internal indicators is that they provide the managers key information on what is precisely required to improve the operations of the project.
11. A finding of the correlation plots was that there was a definite trend of some of the projects being grouped together. The good projects tended to stay in a definite, tight pattern in most of the plots. Conversely, those projects that had lower ratings tended to stay in a pattern.

Table 7-1. List of Variables with Best Correlations

Variable Type	Variable Name
Data Variable	Percent of area with an active water user association
Data Variable	Size of water user association
Data Variable	Time needed for the manager to travel down the main canal
Data Variable	Communications. How often do cross-regulator operators communicate with the next higher level (hr)
Data Variable	Cost of land close to head of canals (\$/ha)
Data Variable	Water charge (\$/ha)
I/TRC Internal Indicator	(I-1) Actual service to individual fields based on traditional irrigation methods (overall weighted)
I/TRC Internal Indicator	(I-1B) Actual service to individual fields based on traditional irrigation methods (flexibility to field)
I/TRC Internal Indicator	(I-2A) Actual service to average point of effective differentiation (number of fields downstream)
I/TRC Internal Indicator	(I-4) Actual service by main canals to subcanals (overall weighted)
I/TRC Internal Indicator	(I-4C) Actual service by main canals to subcanals (equity)
I/TRC Internal Indicator	(I-5B) Stated service to individual fields (flexibility to field)
I/TRC Internal Indicator	(I-10) Cross-regulator hardware of main canal (overall weighted)
I/TRC Internal Indicator	(I-10B) Cross-regulator hardware of main canal (probable ease of cross-regulator operation if system was required to provide better service to turnouts)
I/TRC Internal Indicator	(I-11) Capacities of main canal (overall weighted)
I/TRC Internal Indicator	(I-11C) Capacities of main canal (capacity limitations of structures or canal cross section further down in the canal)
I/TRC Internal Indicator	(I-16) Operation of main canal (overall weighted)
I/TRC Internal Indicator	(I-17) Cross-regulator hardware of submain canal (overall weighted)
I/TRC Internal Indicator	(I-18) Capacities of submain canal (overall weighted)
I/TRC Internal Indicator	(I-20) Communication of submain canal (overall weighted)
I/TRC Internal Indicator	(I-22A) Operation of submain canal (how frequently does the headworks respond to realistic feedback from the canal operators)
I/TRC Internal Indicator	(I-22C) Operation of submain canal (clarity and correctness of instructions to operators)
I/TRC Internal Indicator	(I-25) Water user associations (overall weighted)
I/TRC Internal Indicator	(I-25B) Water user associations (actual ability of the strong WUA to influence real-time water deliveries to the WUA)
I/TRC Internal Indicator	(I-25E) Water user associations (financial strength of WUA)
I/TRC Internal Indicator	(I-26) Ability of present service to individual fields to accommodate pressurized irrigation systems (overall weighted)
I/TRC Internal Indicator	(I-26B) Ability of present service to individual fields to accommodate pressurized irrigation systems (flexibility to field)
I/TRC Internal Indicator	(I-28) Number of turnouts per operator
IWMI/I/TRC Ext.Ind.	IWMI6. Relative irrigation supply (RIS)
IWMI/I/TRC Ext.Ind.	I/TRC3. Water delivery capacity (%)
IWMI/I/TRC Ext. Ind.	I/TRC10. Annual project-level irrigation efficiency (%)

The following discussion focuses data which showed some visual trends, and which also have some logical "cause" and "effect" relationships.

Percent of Area with an Active Water User Association

It is difficult to know whether the "percent area with an active WUA" variable is best described as a *cause* or as an *effect* variable. That is, in some cases it appears that the presence of a WUA will cause certain things to happen - while in other cases it appears that certain other factors will cause a WUA to prosper.

The following figures indicate that there are certain characteristics that must be in place for active water user associations (WUAs) to exist.

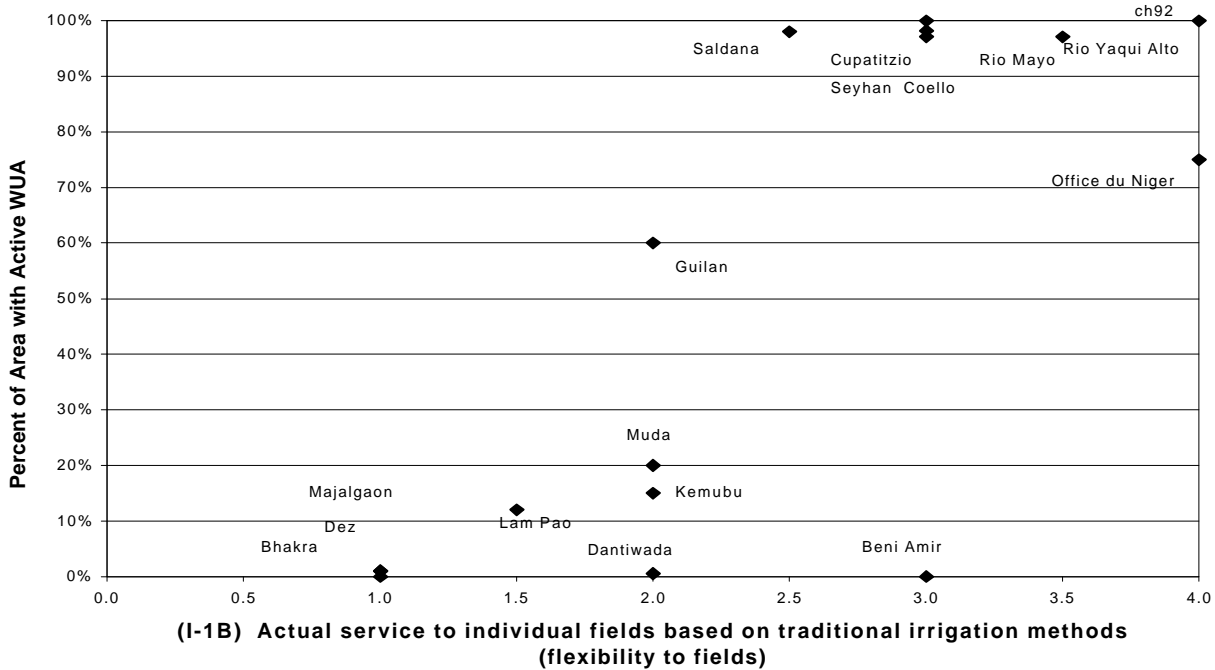


Figure 7-1. Scatter plot between [actual service to individual fields based on traditional irrigation methods (flexibility to fields)] and the [percent of area with an active water user association].

Figure 7-1 shows that there are distinct groupings of projects in regard to the existence of active WUAs. The projects with a high level of flexibility to the individual fields (Saldaña, Cupatitzio, Seyhan, Coello, Rio Mayo, Rio Yaqui Alto, and Office du Niger) have the highest values for the percent of area with water user associations. Those projects with low water delivery service ratings seem to have a problem with getting the water user associations started.

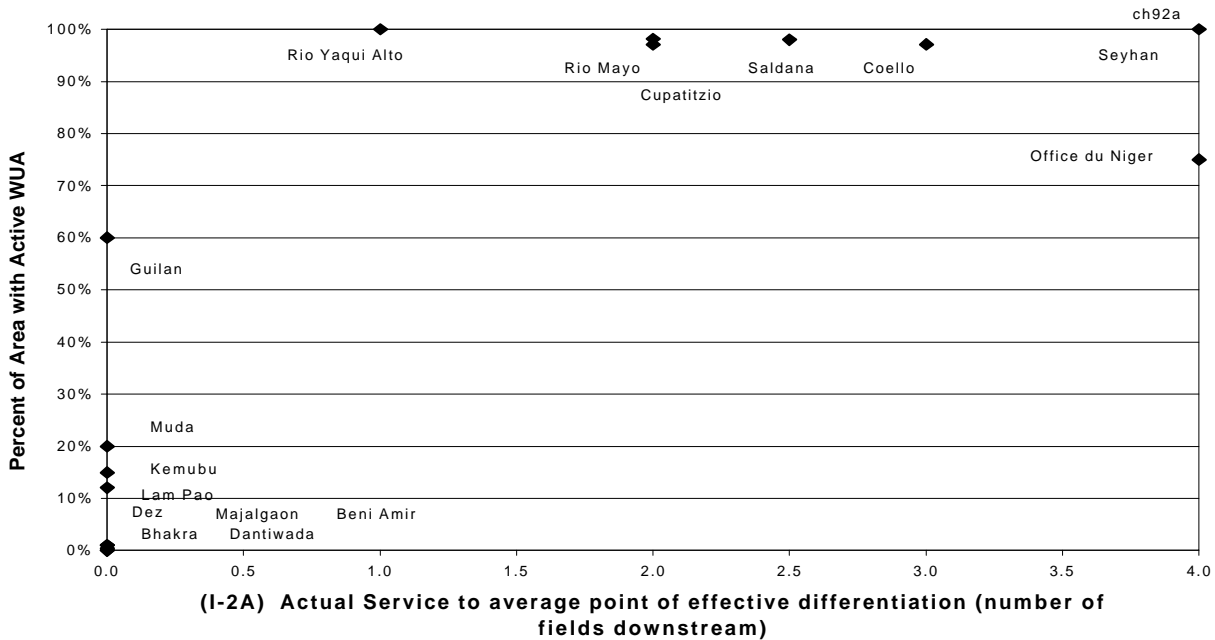


Figure 7-2. Scatter plot between [actual service to average point of differentiation (number of fields downstream)] and the [percent of area with an active water user association].

Figure 7-2 shows a strong grouping of irrigation projects in the lower left-hand corner. Strong WUAs did not exist in any of the Asian projects. It is interesting because incentives had been made available to Indian farmers to encourage them to form WUAs. In Bhakra farmers were promised that the watercourses would be lined if they formed WUAs. In both Majalgaon and Dantiwada farmers were told that if they formed WUAs they would be provided volumetric deliveries and their water charges would be cut by 50%. Indian farmers probably recognize that discussions of volumetric deliveries are meaningless if the water delivery service is very poor. Figure 7-2 shows that in the Asian projects there tend to be a large number of fields downstream of the final point of effective control - meaning that promises to individual farmers cannot be kept because it is almost impossible to treat farmers equitably in such cases.

The projects with a high percentage of active WUAs seem to have several things in common that contribute to the success of implementing a WUA. These systems have a high degree of flexibility in the water delivery service to the individual fields. A good example is the Seyhan irrigation project in Turkey. This project provides good flexibility in the water service to the farmers and there is a strong movement towards the creation of active WUAs.

Another contributing factor to the successful implementation of the WUA is the capacity of the system. Figure 7-3 is a scatter diagram showing the relationship between the water deliver capacity (ITRC 3) and the percent of area with an active WUA. This would indicate that it is necessary to meet a minimum capacity to deliver water to the project in order to encourage the formation of WUAs. Figure 7-3 shows this relationship.

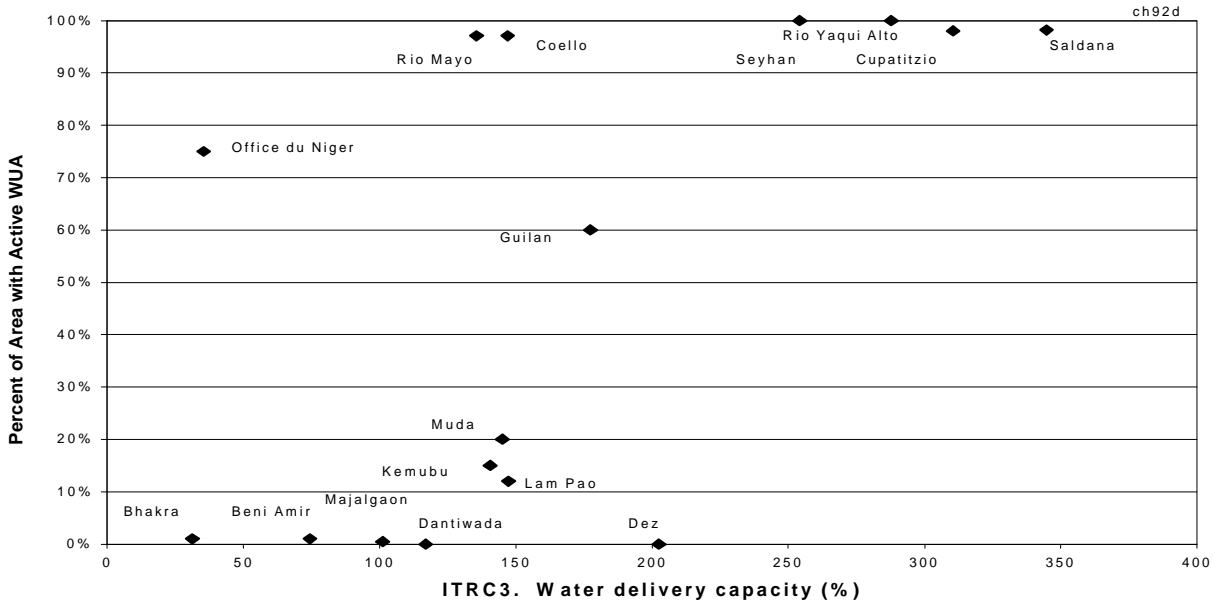


Figure 7-3. Scatter plot between [water delivery capacity] and the [percent of area with an active water user association].

The last figure in this first sequence represents the relationship between the area with an active WUA and the ITRC internal indicator (I-26), which is a measure of the ability of present service to individual fields to accommodate pressurized irrigation systems. This figure shows that there is a link between the creation of effective WUAs and the future transition to pressurized irrigation methods.

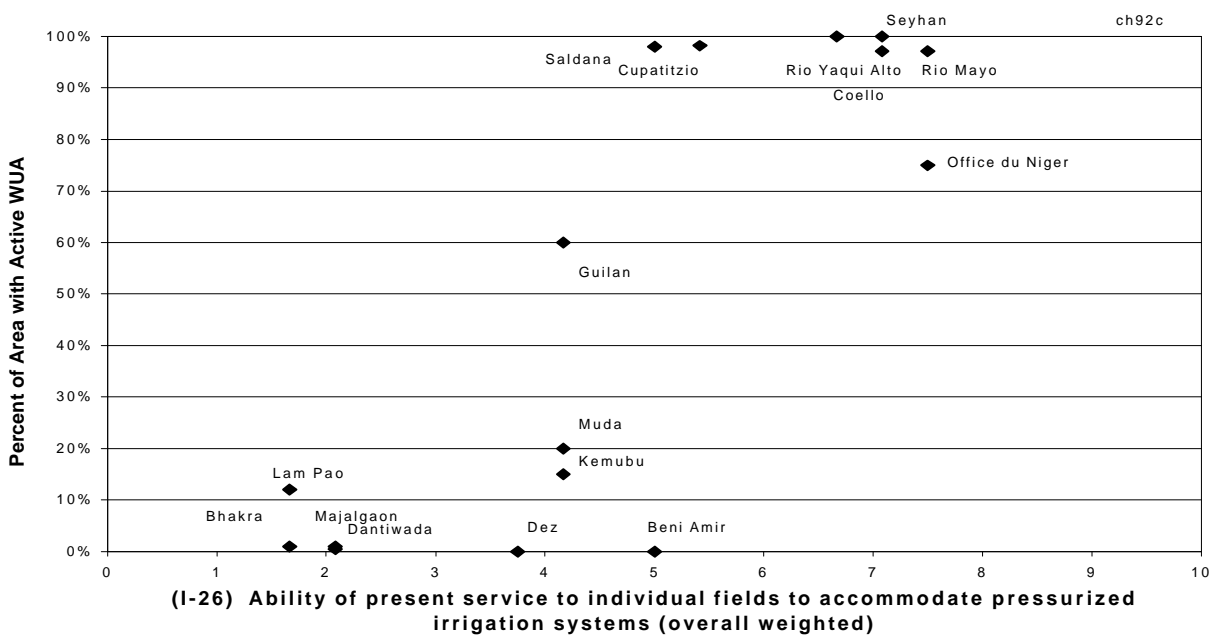


Figure 7-4. Scatter plot between [ability of present service to individual fields to accommodate pressurized irrigation systems] and the [percent of area with an active water user association].

Size of the Water User Association

The following graphs illustrate a trend of increased flexibility and service that is associated with an increase in the size of the water user association.

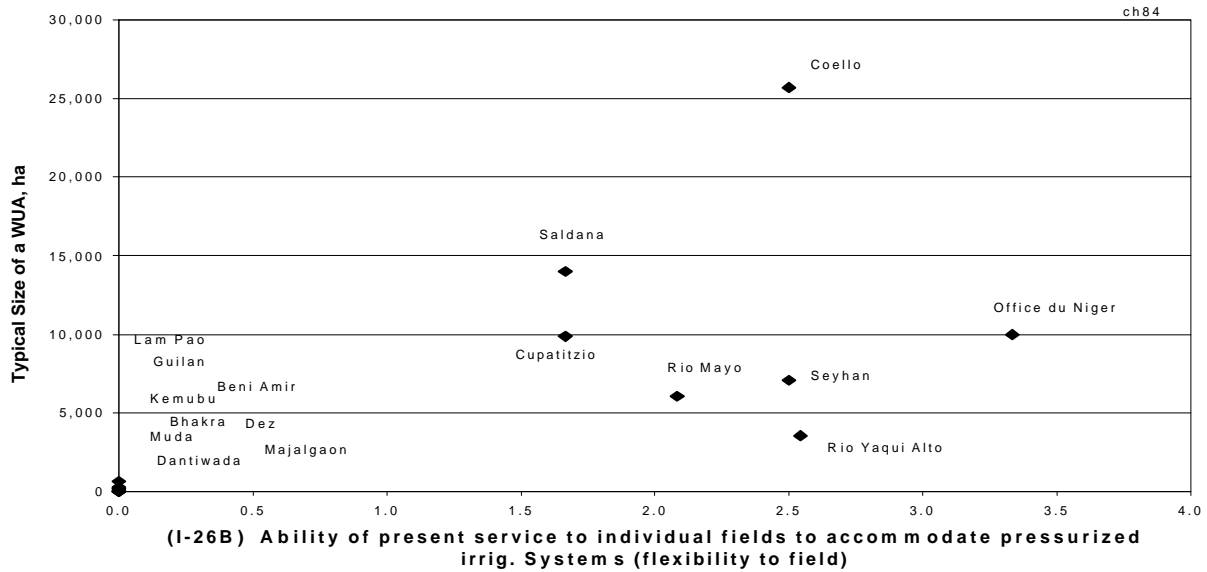


Figure 7-5. Scatter plot between the [ability of present service to accommodate pressurized irrigation systems (flexibility to field)] and the [typical size of a WUA].

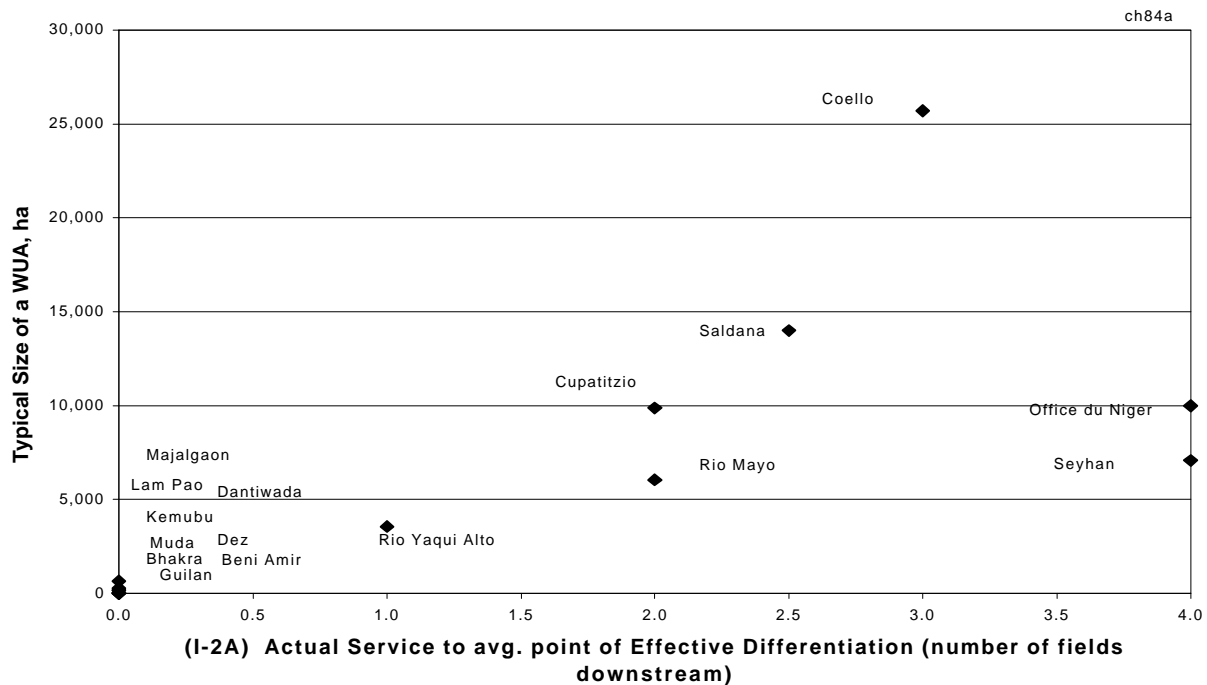


Figure 7-6. Scatter plot between the [actual service to average point of effective differentiation based on traditional on-farm methods (number of fields downstream)] and the [typical size of a WUA].

It is difficult to draw many conclusions from Figures 7-5 and 7-6. However, these figures are interesting because they show that there is not a negative effect due to an increasing size of WUA. In Mexico, it has been noted that WUAs need some minimum size in order to be able to hire qualified managers and staff. This is an important point, as one sometimes hears that WUAs should be small. The difference in perception is probably related to what a person thinks a WUA should do. In Latin America the WUAs operate almost as businesses, and they hire staff to do the actual water distribution. Discussions of village level WUAs (i.e., small WUAs) tend to assume that with the formation of a WUA, farmers will begin to cooperate voluntarily in the distribution of water. In this research, the only successful WUA of this nature was Office du Niger, and in that case voluntary cooperation works well because of the design of the final watercourses. The final watercourses are really miniature reservoirs and there is no hurry to adjust the flows into the watercourses when farmers take water. In other words, Office du Niger farmers do not really need to cooperate to any great extent, because they can individually control the flows into their individual fields without significantly impacting their neighbors. The proper engineering design has minimized the need for close inter-personal cooperation.

Time Needed for the Manager to Travel Down the Main Canal

The "time needed for the manager to travel down the main canal" variable is one indication of the level of communication that occurs on a project. There is a significant amount of contrast between the projects with respect to the ability to readily move through the project. Some projects have an excellent paved road system that parallels the canals. On other projects, the canal roads are the only roads available to the farmers and the project personnel, and those roads are in poor condition.

Figure 7-7 demonstrates there is a negative relationship between the time needed for the manager to travel down the longest canal and the ITRC internal sub-indicator (I-5B) which is the stated service to fields - flexibility to field. The indicator shows that on those projects where the manager has difficulty getting down the canals, the stated water delivery service to fields is the lowest. The one exception is the Office du Niger project where the stated service to the fields is very high (perfect 4.0), even though the main canal is not accessible at many points. Office du Niger is not a "typical" design, however, in that its main conveyance canal is operated with considerably less flexibility than the lower canal reaches. Office du Niger has relatively small operational units, and during the dry season the travel was reasonably easy on a motorbike within the units that were visited.

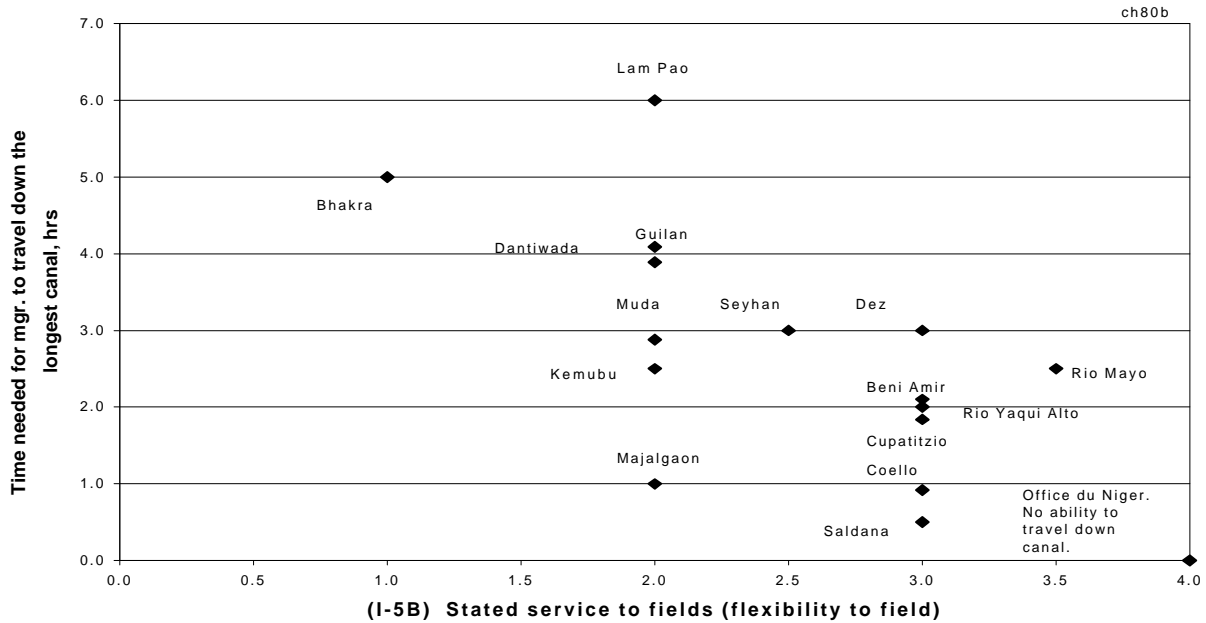


Figure 7-7. Scatter plot between the [stated service to fields (flexibility to field)] and the [time needed for the manager to travel down the longest canal].

An interesting negative correlation is found between the water charge and the time needed for the manager to travel down the longest canal. It appears that those systems with the worst access have the least expensive water (Figure 7-8).

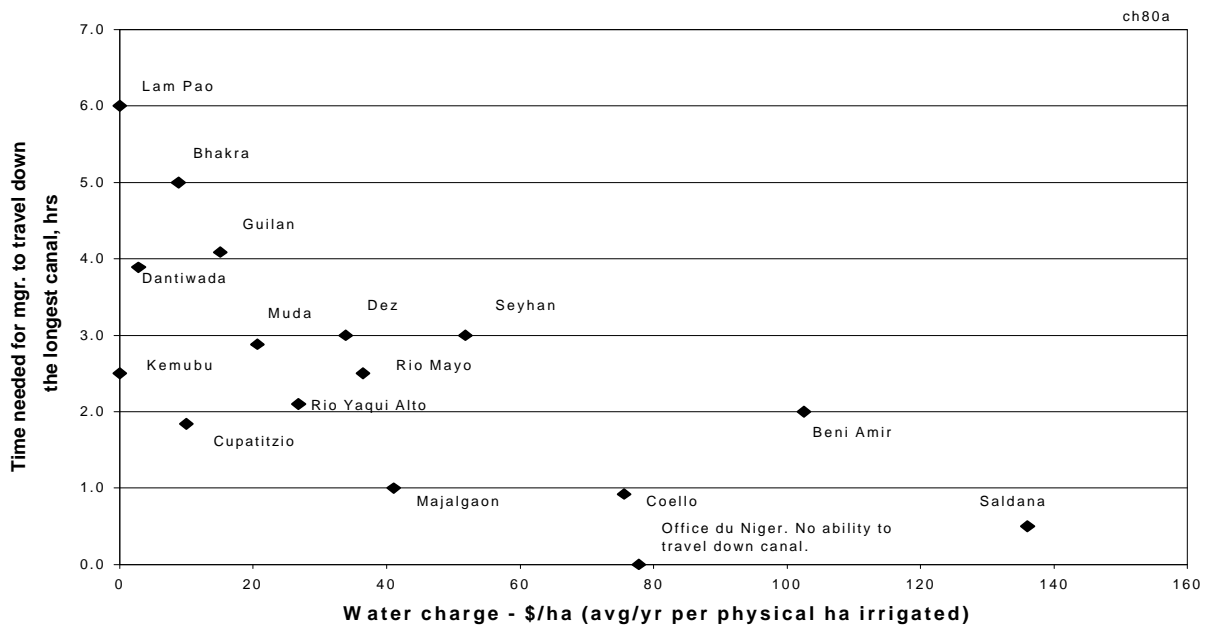


Figure 7-8. Scatter plot between the [water charge] and the [time needed for the manager to travel down the longest canal].

Those projects that have a poor transportation network seem to have a lower level of service in general. Figure 7-9 shows the relation between the time needed for the manager to travel down the longest canal and the ITRC internal indicator I-22A (how frequently does the headworks of the submain canal respond to realistic feedback from the canal operators).

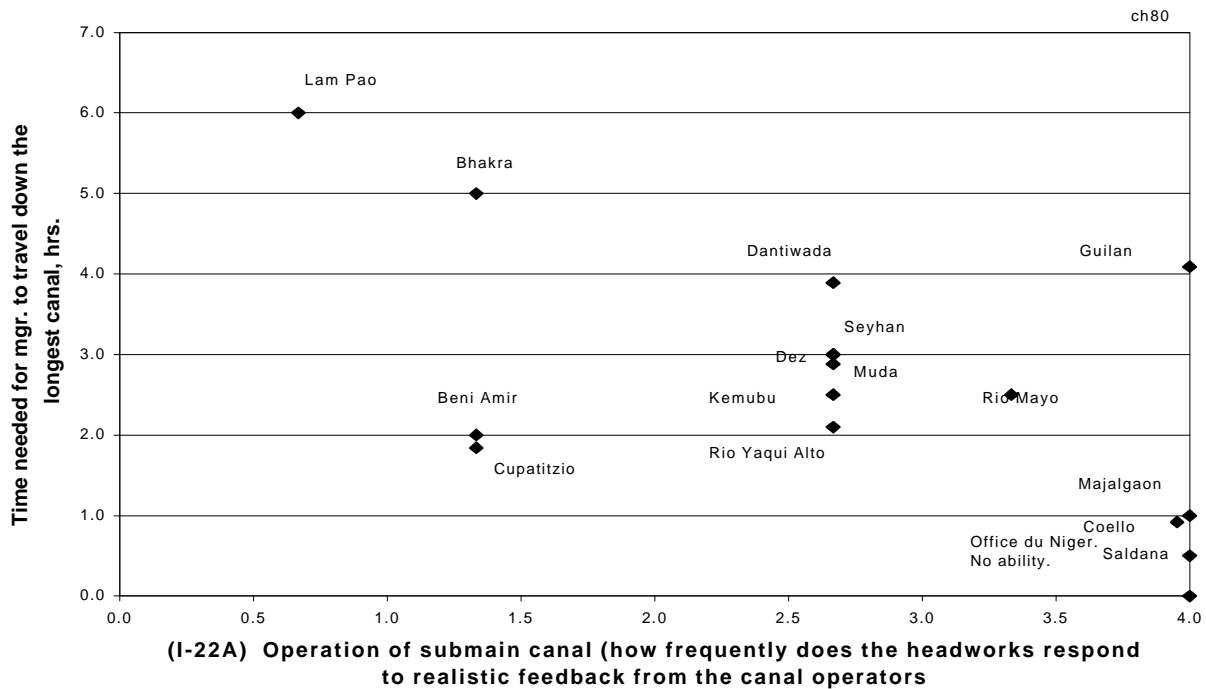


Figure 7-9. Scatter plot between [operation of submain canal (how frequently does the headworks respond to realistic feedback from the canal operators)] and the [time need for the manager to travel down the longest canal].

Figure 7-9 shows that in general, if the main canal is easily accessible, then the headworks to the submain canals are operated quite well.

Communications - How Often do Cross-Regulator Operators

Communicate with the Next Higher Level (Hr)

This is another communication variable that is related to the type of service provided. Figure 7-10 shows that most projects communicate on 3, 12, 24 or 48 hour time increments. Those projects with the highest increments (48 hours) appeared to have the biggest problem with inequity in the project. A special note is needed here regarding Office du Niger. That project is somewhat of a mix. It has areas which have been modernized (those which receive excellent flexibility at the field level) and other areas outside of the modernized zones. In those unmodernized zones there is a strong sense of inequity, which shows up on Figure 7-10.

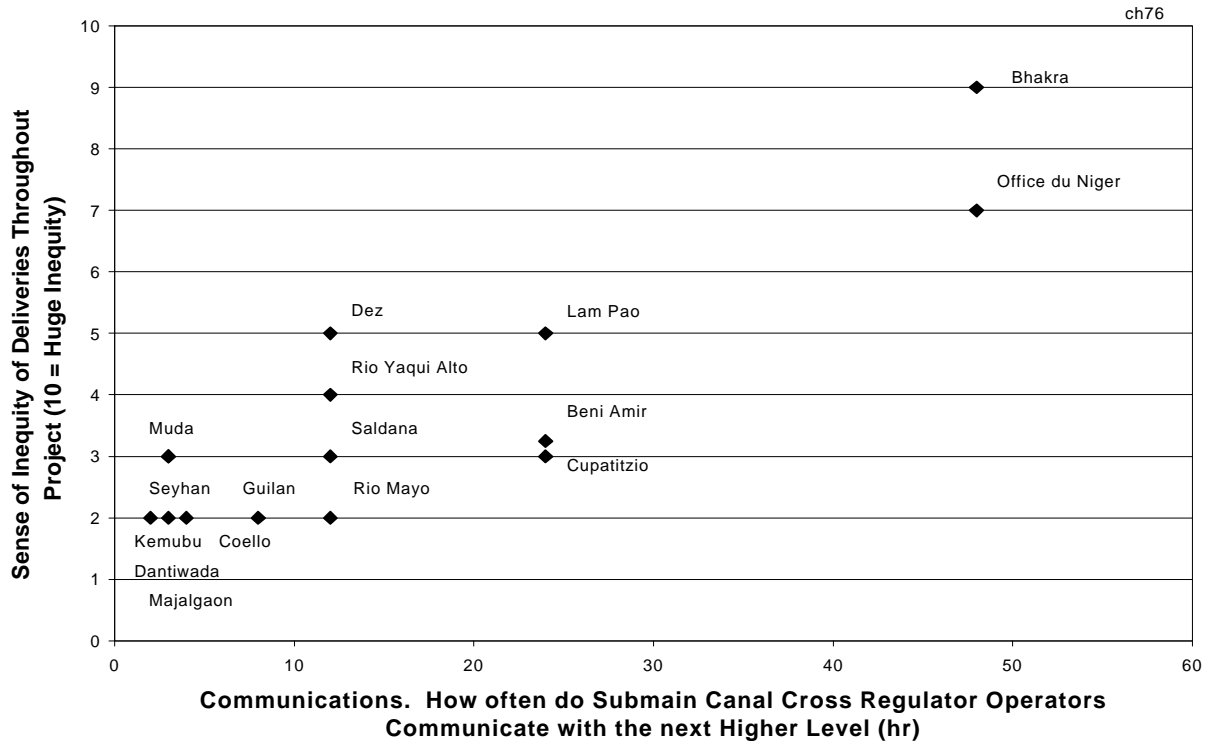


Figure 7-10. Scatter plot between [communications - how often do cross-regulator operators communicate with the next higher level] and the [sense of inequity of deliveries throughout the project].

Figure 7-11 shows that the frequency of communication is also related to the ITRC internal indicator I-16 (the operation of the main canal- weighted overall). This should not be surprising, since, in general, a canal can only be operated properly if the canal is easily visited and there are frequent updates for the operators. There are a few points to note: Both Lam Pao and Rio Yaqui Alto have frequent communications, but the main canal is operated poorly. In these two projects, even though some information is frequently updated, the information which is passed back to the headquarters is fairly meaningless and the operators of the canal are given poor or incorrect instructions. The frequent communications are not really used to answer operational questions nor to answer spur-of-the-moment questions by operators so that they can respond to changing conditions. In general, the communications are solely used to pass numbers back and forth for archival purposes or for incorrect field instructions.

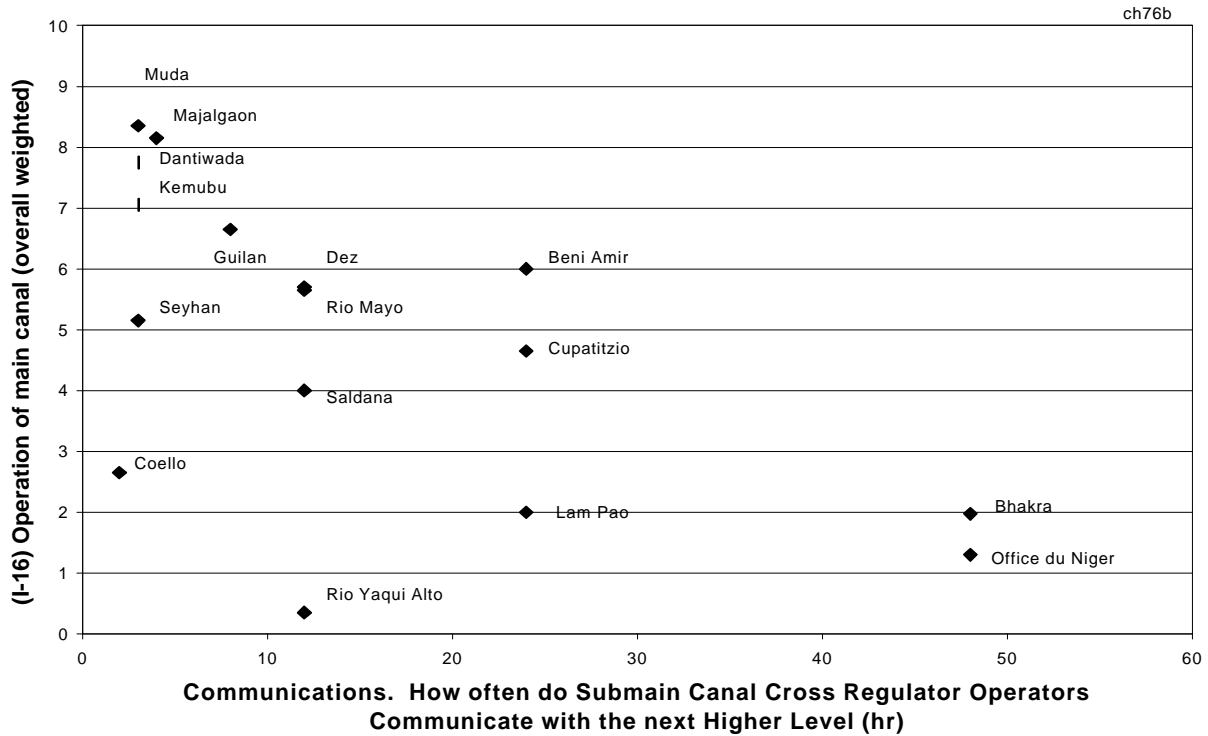


Figure 7-11. Scatter plot between [communications - how often do cross-regulator operators communicate with the next higher level] and the [operation of the main canal].

Cost of the Land Close to the Head of Canals

The "cost of land close to the head of canals" is an interesting indicator that is correlated with several other factors. Those projects with the least amount of flexibility and experiencing poor service are the ones with the most expensive land costs. For example, the land acquisition costs on the Bhakra project in India are a major restriction for the expansion of the water delivery system.

The projects with a high cost of land generally do not have many land sales. These projects are characterized as having land that is transferred by inheritance. Most of these projects also are characterized as having small land holdings due to the inheritance and land splitting that has occurred over time. Figures 7-12 and 7-13 generally show that there is a decrease in the service of water delivery as the cost of land is increased.

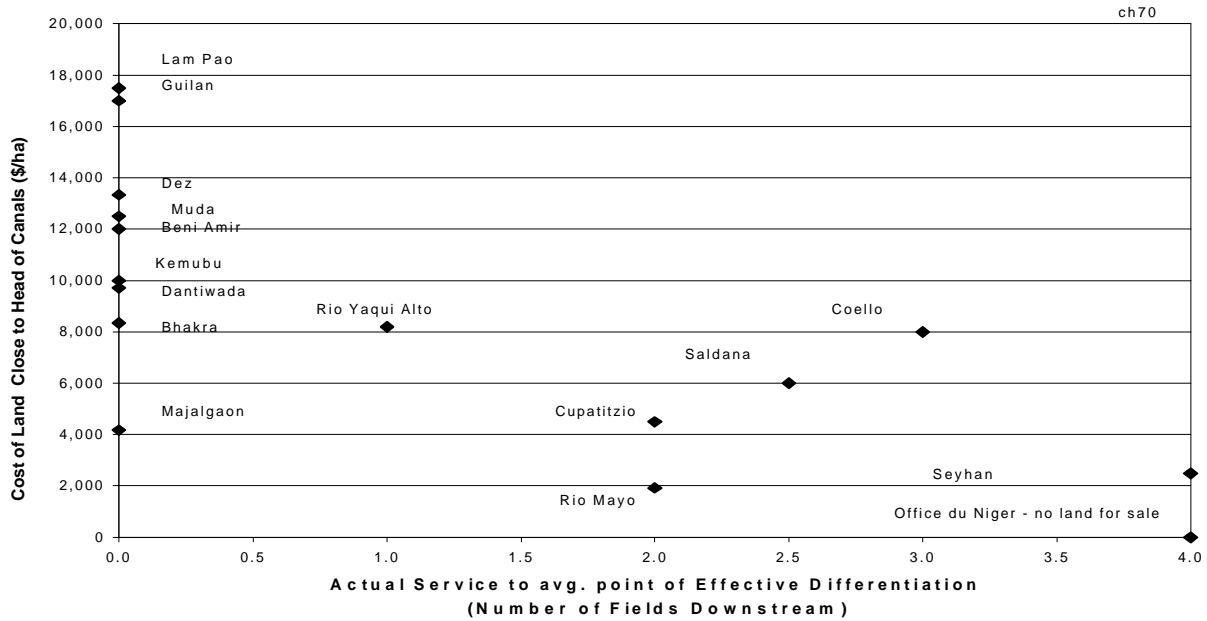


Figure 7-12. Scatter plot between the [actual service at point of effective differentiation (number of fields downstream)] and the [cost of land close to the head of canals].

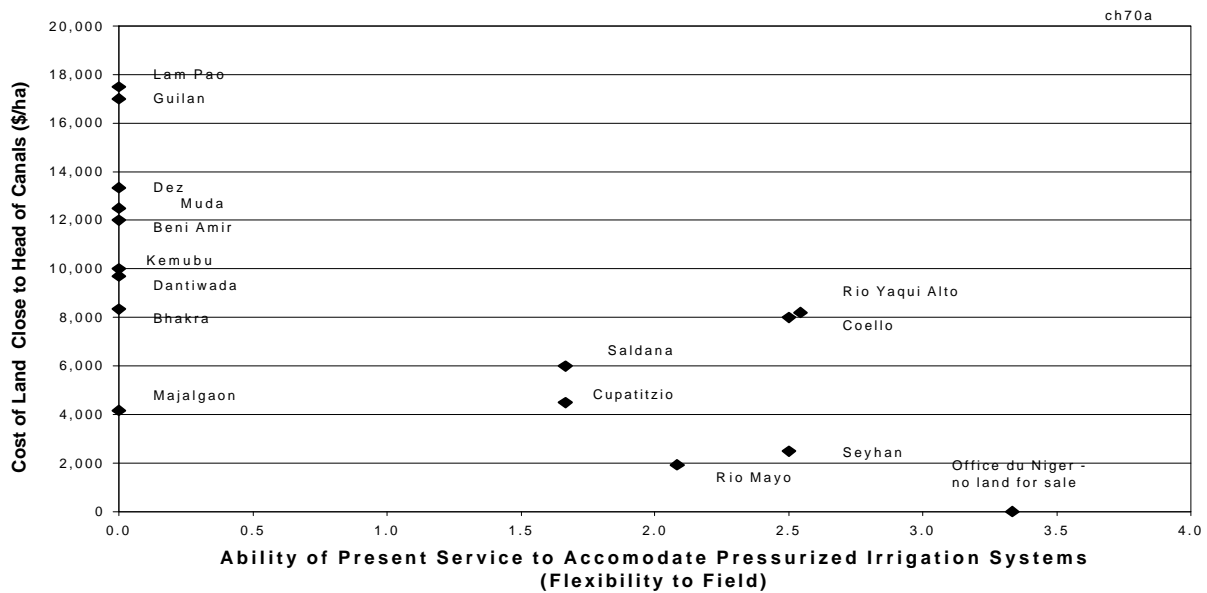


Figure 7-13. Scatter plot between the [ability of present service to accommodate pressurized irrigation systems (flexibility to field)] and the [cost of the land close to head of canals].

The previous figures bring up some intriguing questions. Why is the water service typically so low in areas with the most expensive land? And since it will be shown later that the yields also tend to be low in those same areas, wouldn't it be worthwhile to invest more in irrigation infrastructure and improved irrigation project operation to increase the yields? In these areas, the

value of the land *in terms of production per hectare* is low, yet the purchase price is high. Therefore, the incremental cost of improved irrigation should have dramatic economic impacts.

Figure 7-14 shows another relationship with the cost of the lands and the WUAs. The projects with the best ratings for the WUAs are the projects with the lowest land costs. Again, there is a definite grouping of the Latin American projects (along with the Seyhan project), that have excellent ratings for WUAs and lower land costs.

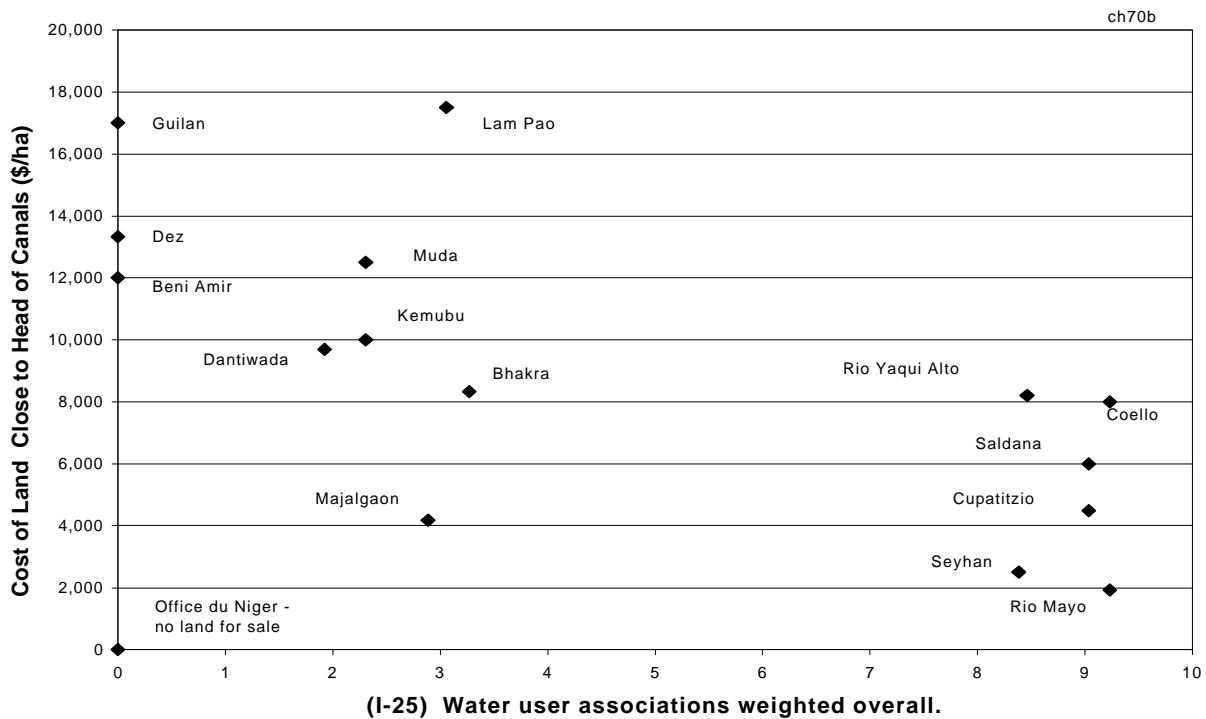


Figure 7-14. Scatter plot between the [water user associations (weighted overall)] and the [cost of the land close to head of canals].

Actual Service to Individual Fields Based on Traditional Irrigation Methods

While this ITRC internal indicator (I-1) did not show big differences in the overall service ratings, there were several graphs that appear to show correlations between this variable and several of the internal process indicators.

Figures 7-15 and 7-16 support one of the original hypothesis statements regarding the clarity and correctness of instructions for the operators.

- *Reliable service at field turnouts will only be found if levels of service are clearly defined and understood by operators and management at all layers within the system.*

These two graphs show that this hypothesis appears to be true. The general trend is that there needs to be clarity and correctness in the instructions in order for projects to have good service at the turnouts to the individual fields.

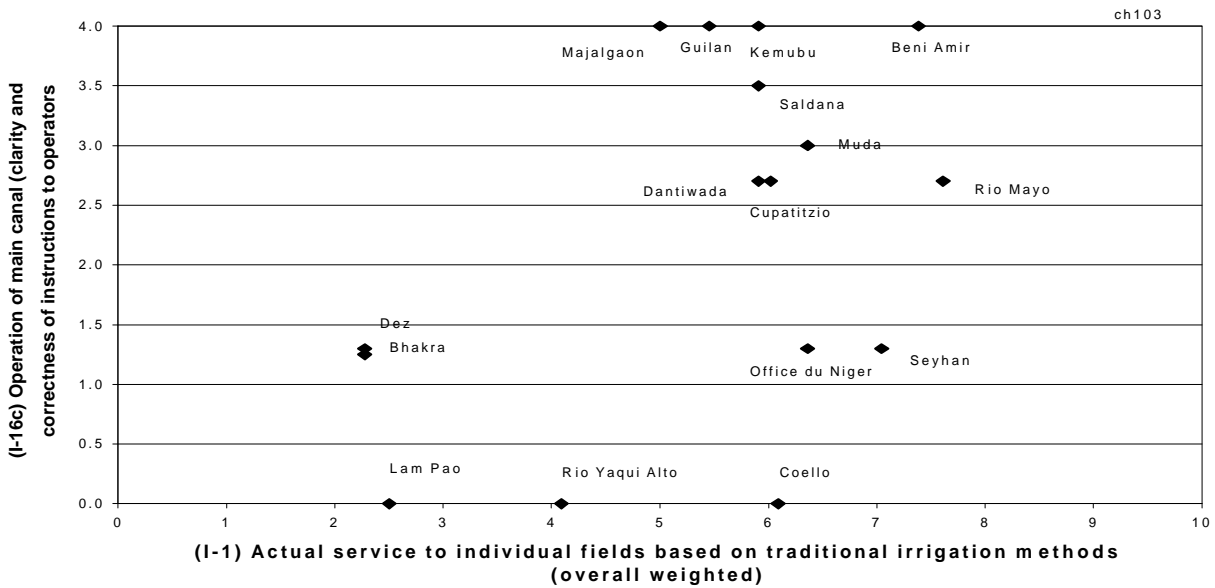


Figure 7-15. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [operation of the main canal (clarity and correctness of instructions to operator)].

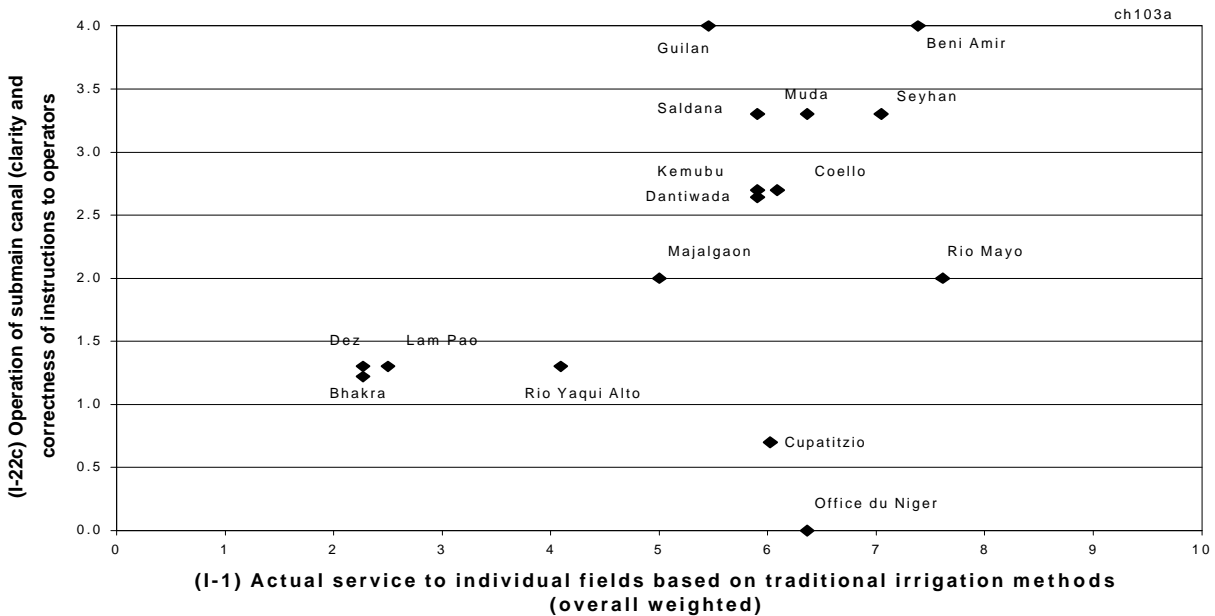


Figure 7-16. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [operation of the submain canal (clarity and correctness of instructions to operator)].

Figure 7-17 shows evidence of one of the strongest relationships between a service variable and the instructions provided to operators. This graph points to Lam Pao, Dez, Bhakra and Rio Yaqui Alta as the projects that have both low service ratings to the individual fields and low ratings for the service between canal levels in the system. One of the hypothesis statements for this research was that certain institutional frameworks needed to be in place in order for a project to provide a high level of water delivery service.

- Certain institutional frameworks are always present in projects that provide a high level of water delivery service to individual fields.

It appears that good service from the main canals to the submain canals is a key indicator for providing good service to the field level. This was true on several of the projects that rated high in both categories, such as Rio Mayo and Seyhan.

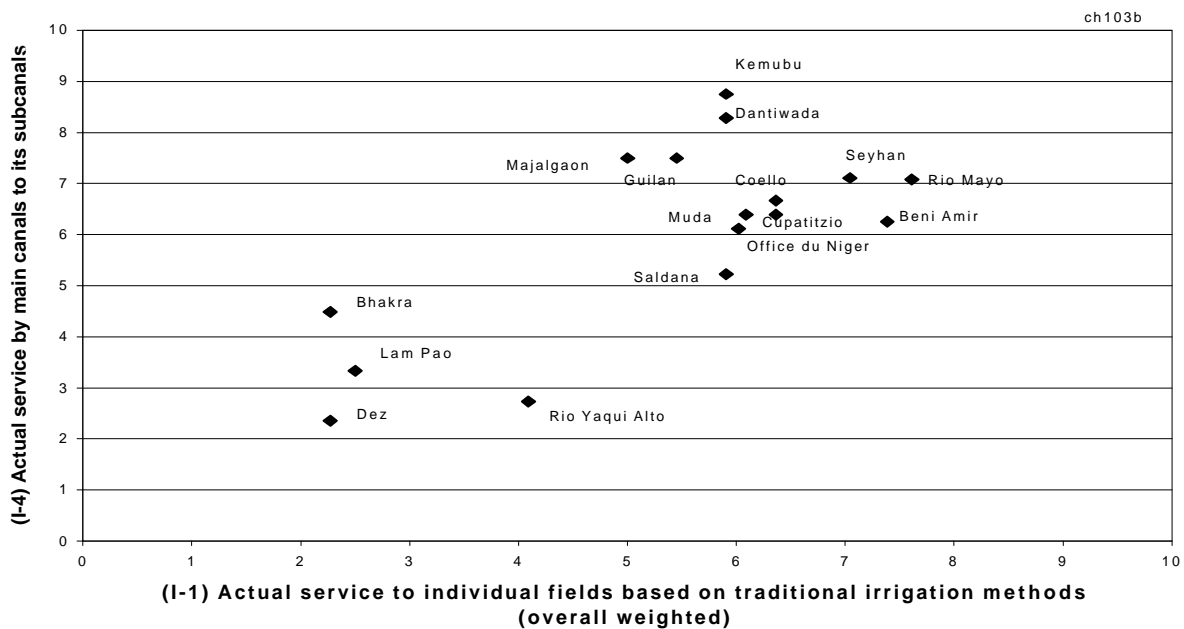


Figure 7-17. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [actual service by main canals to its subcanals].

In the research proposal, those projects with unreliable service to the individual fields were predicted to have some degree of chaos.

- Failure to provide a promised and clearly defined level of service to farmer fields will be associated with problems as water stealing, destruction of structures, lack of farmer discipline, and failure to pay for water.

Figure 7-18 addresses the occurrence of anarchy. Bhakra and Dez were the only projects evaluated where there were significant levels of anarchy observed. The farmers were not damaging structures beyond repair, but there were documented problems with water stealing and vandalism in both projects.

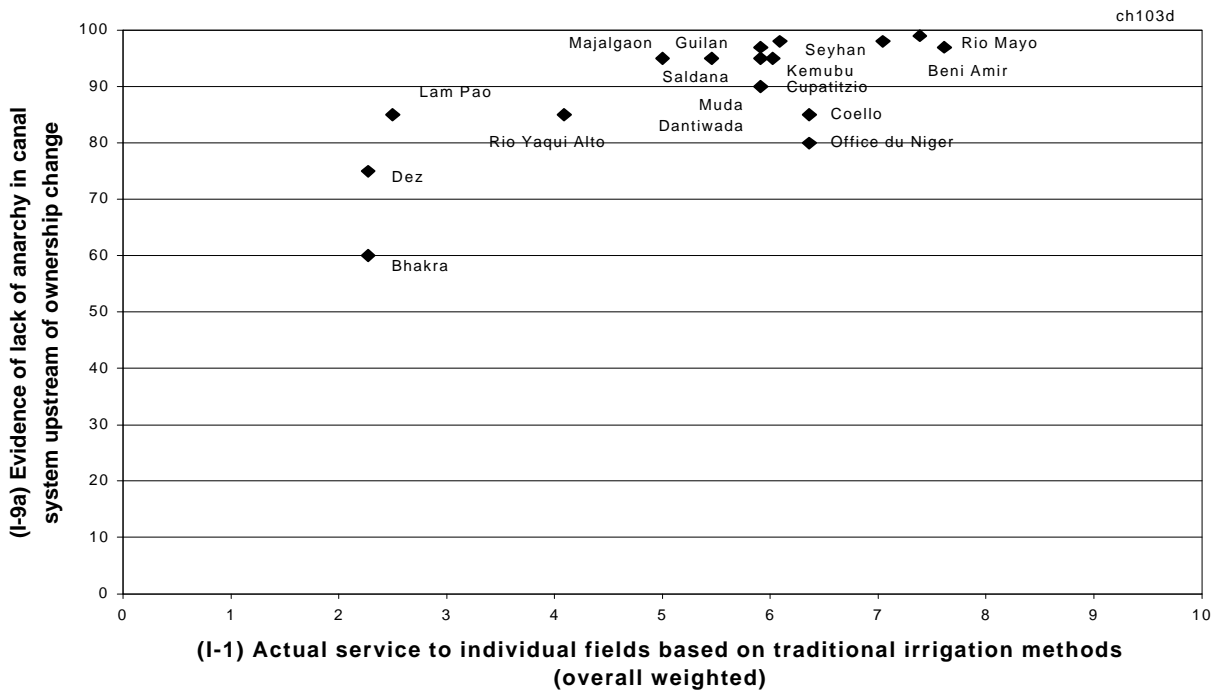


Figure 7-18. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [noticeable non-existence of unauthorized turnouts from canals above point of ownership change].

Perhaps the most significant point to be learned from Figure 7-18 is that all of the projects, with the exception of Bhakra, have some aspects of modernization. While none of the projects received perfect scores, in general there was minimal anarchy in these systems. This is in sharp contrast to previous studies that have noted extreme chaos and anarchy in traditional irrigation projects. Instead, this research project shows relatively optimistic results.

Figure 7-19 shows that there is a limited relationship between the level of service provided to the individual fields and the output of the project. The IWMI production based external indicators (IWMI1, IWMI2, IWMI3, and IWMI4) did not show good correlations with any of the other variables based on the Pearson Correlation coefficient. This may be partly due to the problems with collecting meaningful economic data using the rapid appraisal process (RAP). However, the poor correlation seemed more closely related to other factors such as the prices of commodities and the types of crops which could be grown in each project. For example, Rio Yaqui Alto had a high percentage of the area cultivated with tobacco which is a very high value crop.

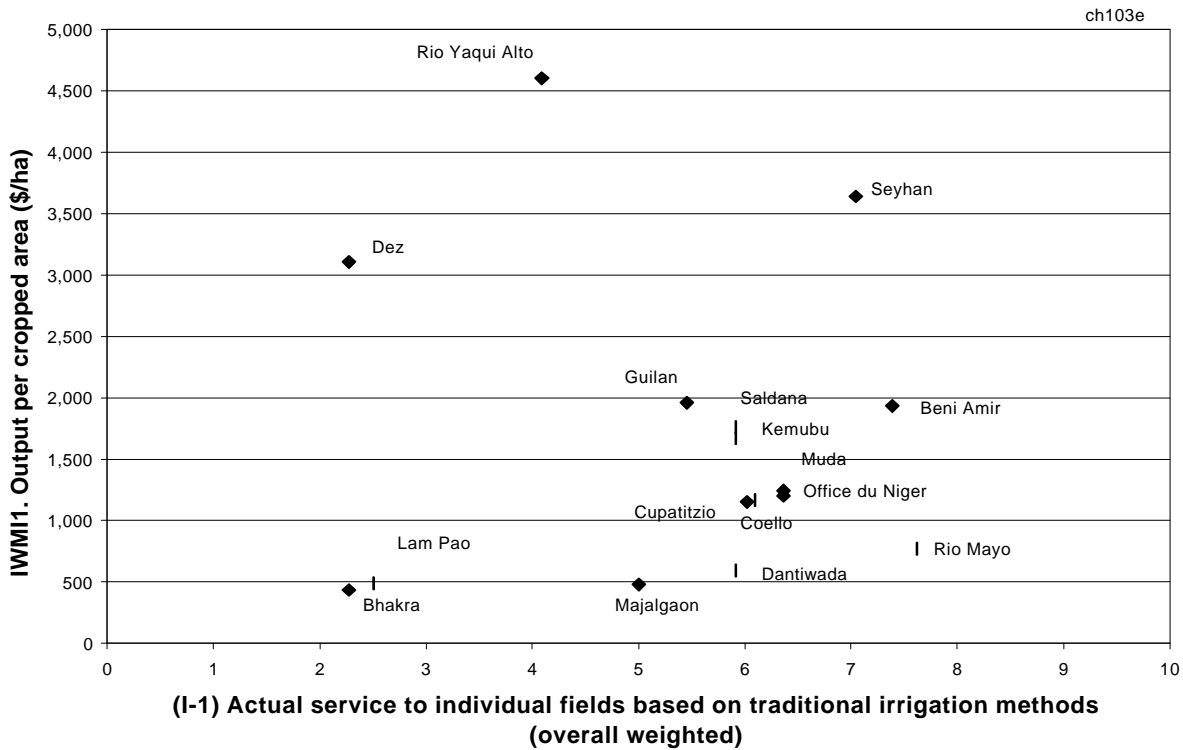


Figure 7-19. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [output per cropped area].

Figure 7-20 shows there is a fairly good relationship between the number of farmers involved in the final stage of the water delivery and the level of service provided to the field. There appears to be a significant linkage between service and trying to get a high number of farmers to cooperate. It is important to note that "modern" irrigation projects do not rely on inter-farmer cooperation.

The critical need identified by the farmers in the Bhakra project was funding for additional concrete lining of the watercourses to the field level. They sincerely believed that the concrete lining would solve the biggest problem they have -- water stealing. The problem is that the concrete lining would not address the basic problem of the high number of farmers who must cooperate. The perception of water theft may be decreased, but the service to the farmers would still be much poorer when compared to the other projects.

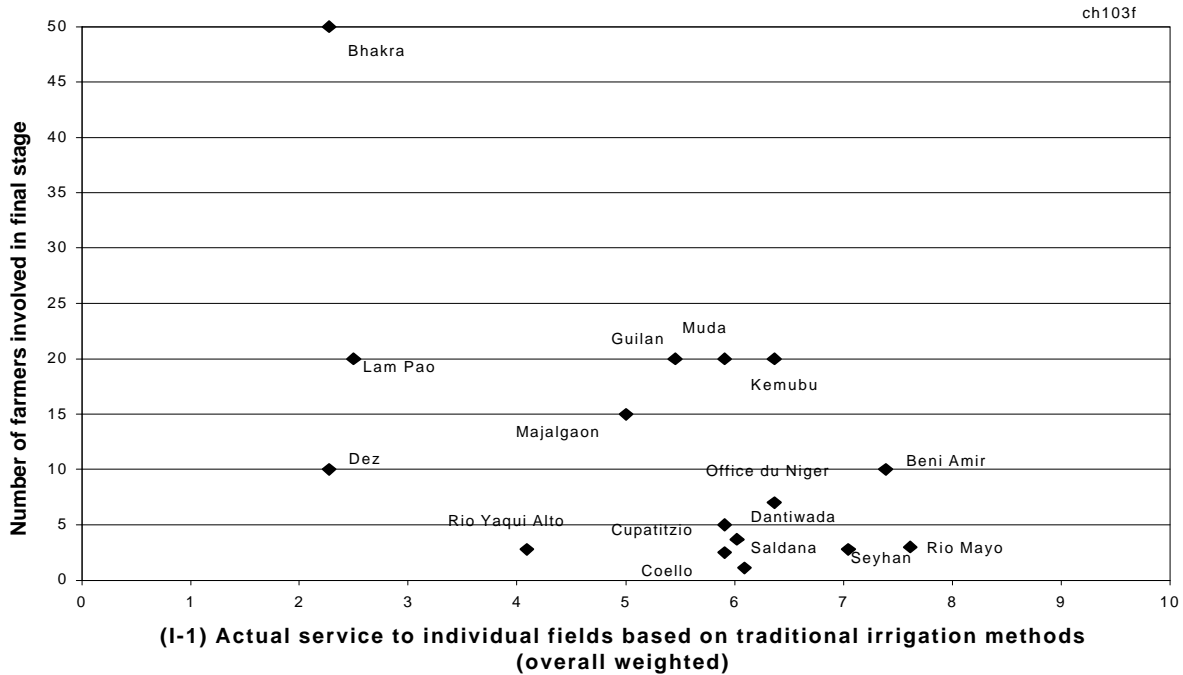


Figure 7-20. Scatter plot between the [actual service to individual fields based on traditional irrigation methods (weighted overall)] and the [number of farmers involved in the final stage].

Actual Service by Main Canals to Its Subcanals

The next set of graphs show the correlation between the ITRC internal indicator I-17 and several other internal process indicators. These graphs show that there is a strong relationship between the service provided and the operations of the cross regulators.

Some of the projects are consistently on the low end of the graphs (Lam Pao, Dez, Rio Yaqui Alto and Bhakra). These projects have also been on the low end of the indicators on several of the previous correlation categories.

The Kemubu project consistently scores well in this section because the downstream control and automated gates on the main canal are coupled with the long crested weirs on the submain canals. Majalgaon also has excellent ratings based on the dynamic regulation concept for the main canals and the long crested weirs on the submain canals.

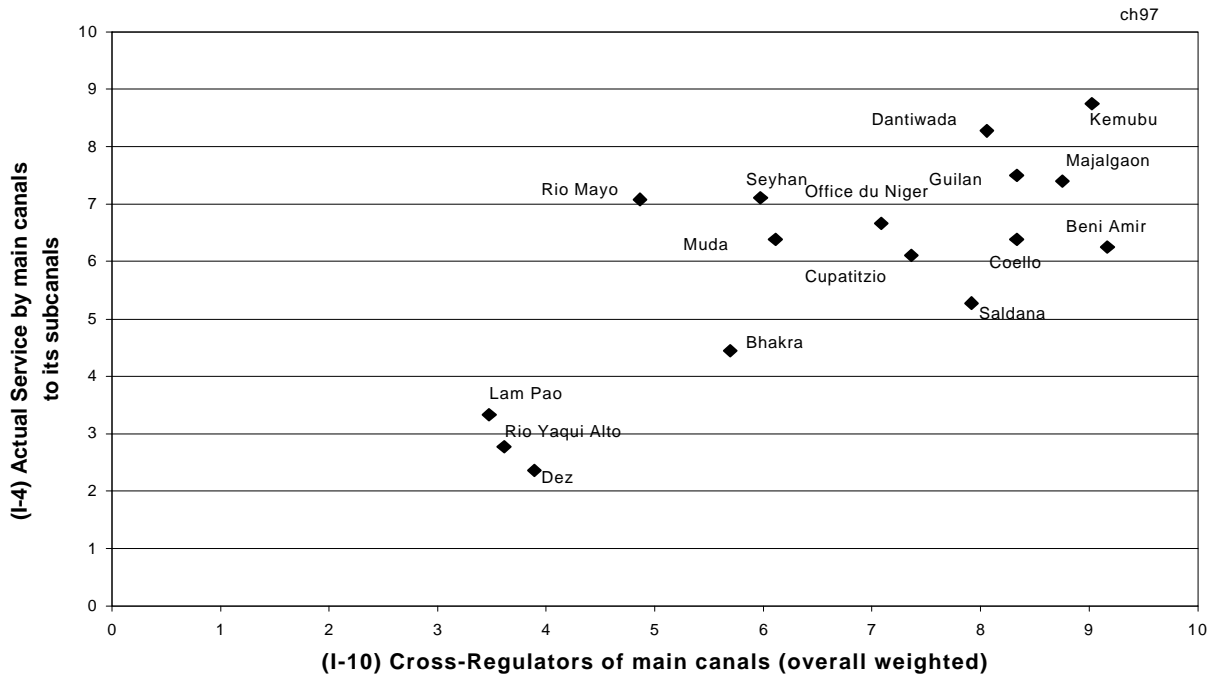


Figure 7-21. Scatter plot between [cross-regulators of main canals] and the [actual service by main canals to its subcanals].

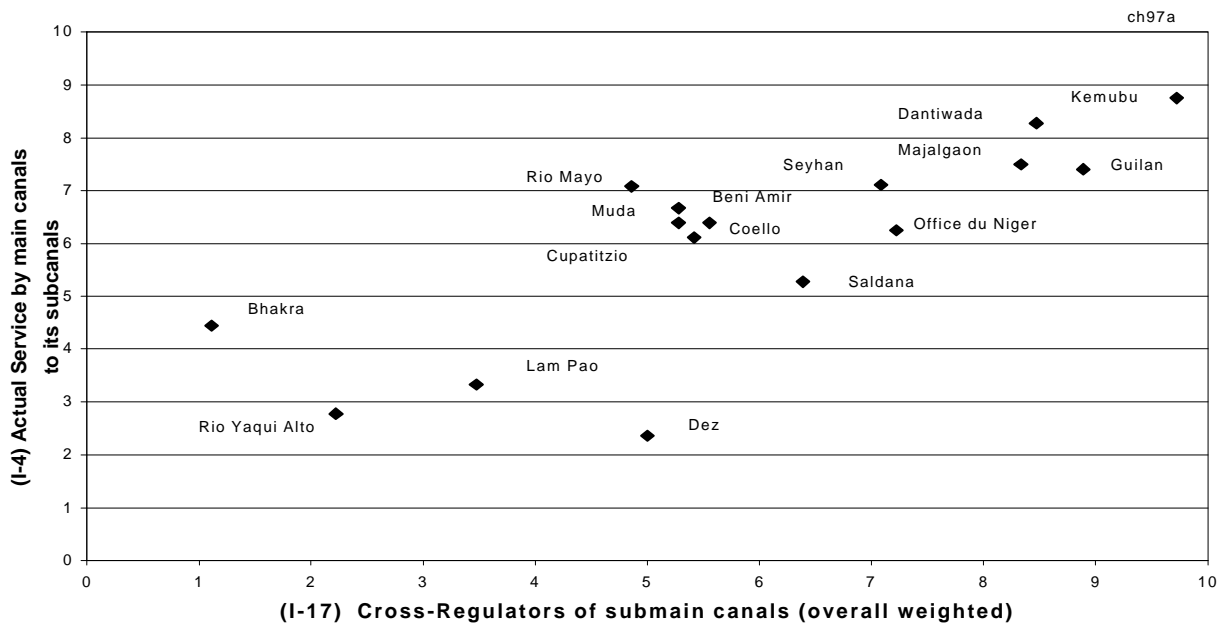


Figure 7-22. Scatter plot between [cross-regulators of submain canals] and the [actual service by main canals to its subcanals].

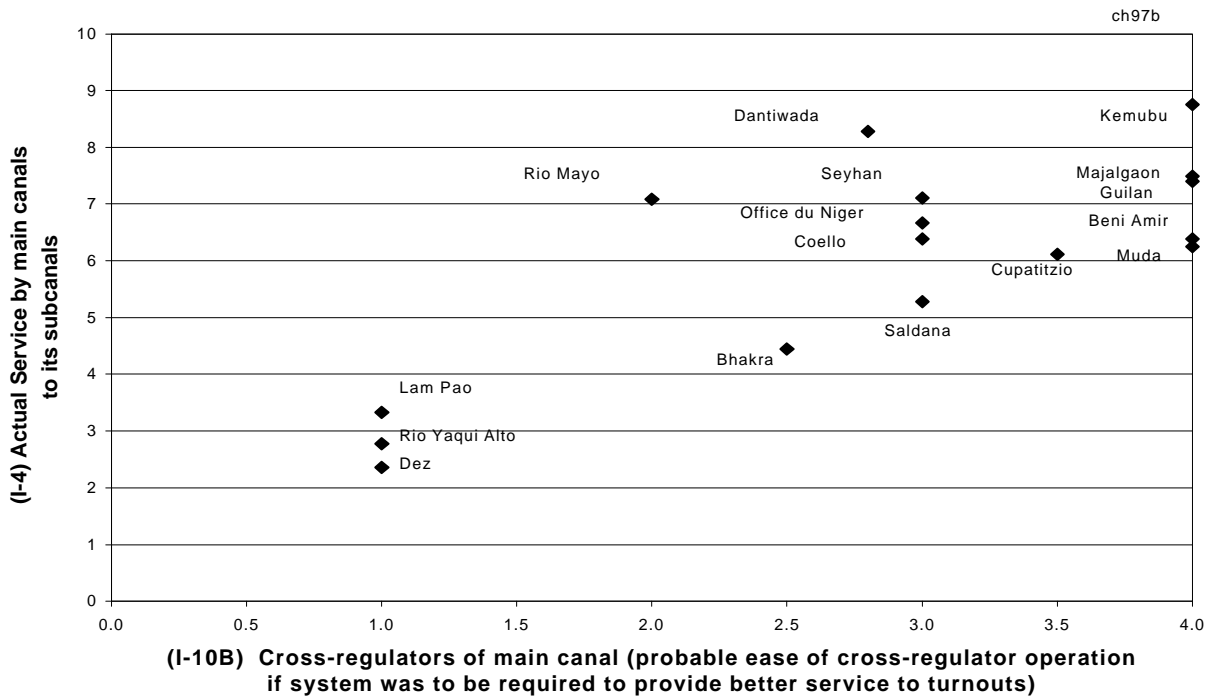


Figure 7-23. Scatter plot between [cross-regulators of main canal (probable ease of cross-regulator operation if system was required to provide better service to turnouts)] and the [actual service by main canals to its subcanals].

Capacities

The capacity of the project delivery system is negatively correlated to the project efficiency of the project. There are several capacity variables that can be used for the evaluation. The following graphs use a combination of the ITRC internal process indicators and the IWMI/ITRC external indicators to illustrate the correlations.

The projects with the highest efficiency are the ones with the smallest capacities. An erroneous conclusion might be that it best to design projects with a restriction in the flow rate capacities in order to force the projects to have better irrigation efficiency. At first glance, this appears to be the logical conclusion. However, project efficiency is only one measure of the performance of the system. Too much emphasis on the project efficiency can lead to incorrect design criteria. The two projects with the highest efficiency, Beni Amir and Bhakra, are not the best projects in other areas, such as economic performance or the lack of anarchy. Nor are they highly rated in their ability to support farmers who want to switch to modern pressurized field irrigation methods.

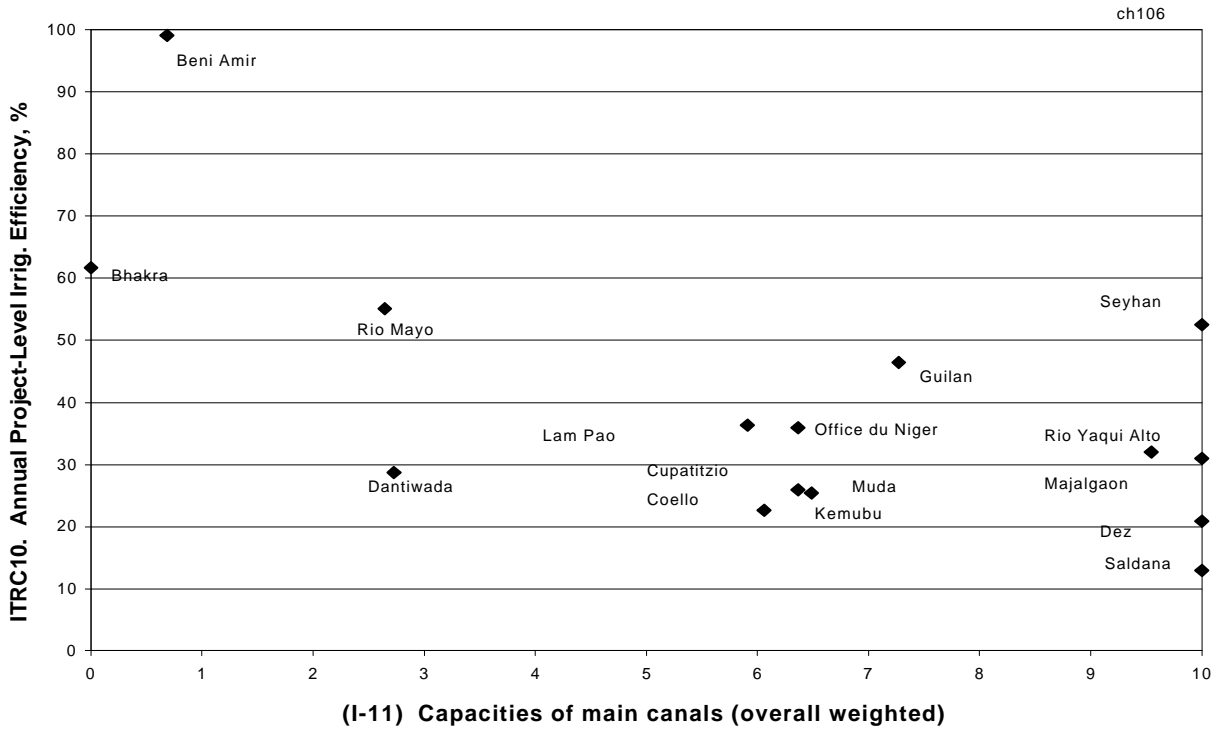


Figure 7-24. Scatter plot between [capacities of main canals (overall weighted)] and the [annual project-level irrigation efficiency (ITRC 10)].

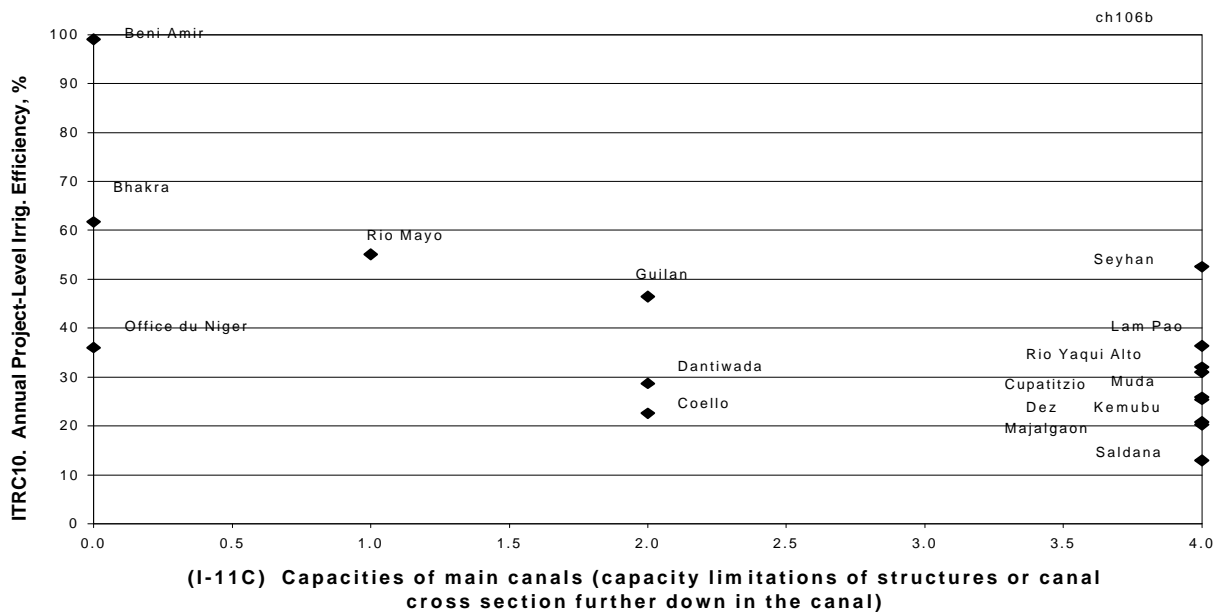


Figure 7-25. Scatter plot between [capacities of main canals (capacity limitations of structures or canal cross sections further down in the canal)] and the [annual project-level irrigation efficiency (ITRC 10)].

Figure 7-26 shows that there is strong a relationship between the water delivery capacity and the ITRC internal indicator I-25 (water user associations). This may be an important point - if there is a large flow rate capacity, it is easier to form and sustain a water user organization.

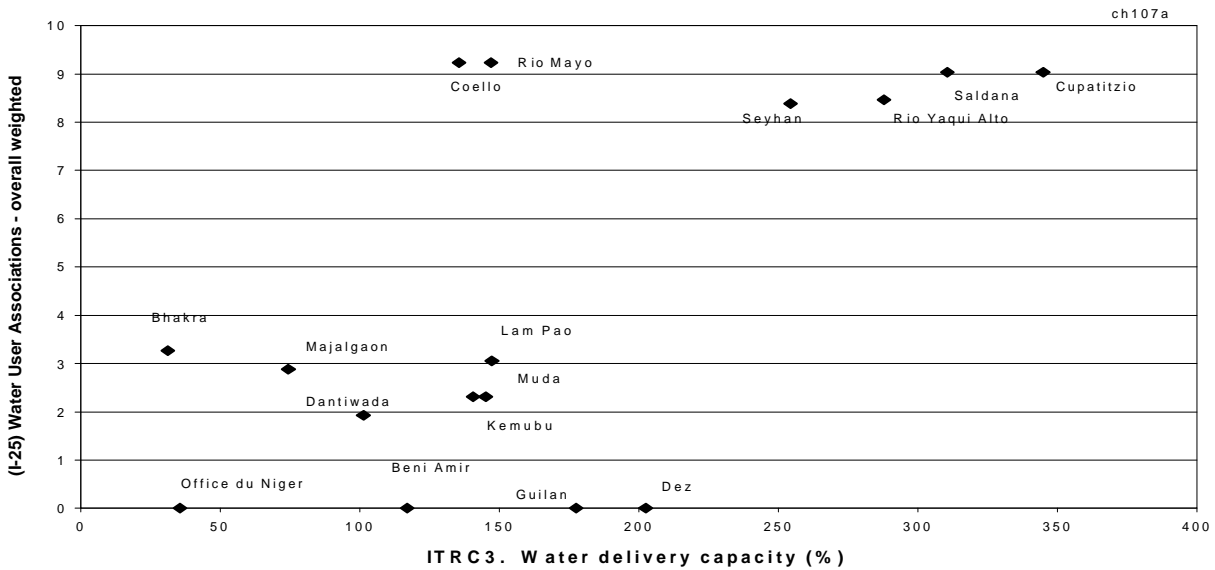


Figure 7-26. Scatter plot between [water delivery capacity] and the [percent of area with an active water user association].

Figure 7-27 shows that the IWMI external indicator IWMI 7 (Relative Irrigation Supply) is not equivalent to the inverse of the annual project irrigation efficiency. The idea that these variables were related had been proposed in Molden et al., (1998).

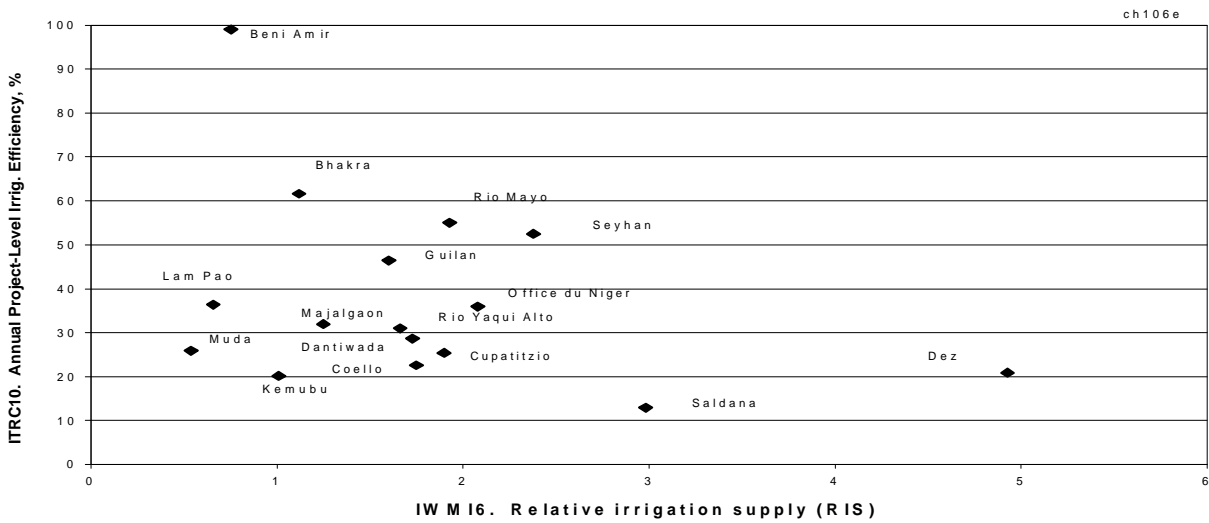


Figure 7-27. Scatter plot between [Relative Irrigation Supply, RIS] and the [annual project-level irrigation efficiency (ITRC 10)].

Percentage of O&M Collected

The "percentage of O&M collected" is an ITRC external indicator (ITRC9rev). This variable did not correlate well with many other variables.

Figure 7-28 shows a relationship between the percent O&M collected and the service indicator to the individual fields based on equity (I-1D). This relationship indicates that there is a link between the service and the capability of the project to collect irrigation fees. Some projects do not have immediate plans to collect irrigation water fees (Lam Pao and Kemubu) and it has been proposed in the northern India project (Bhakra) that the water is also provided for free to the farmers.

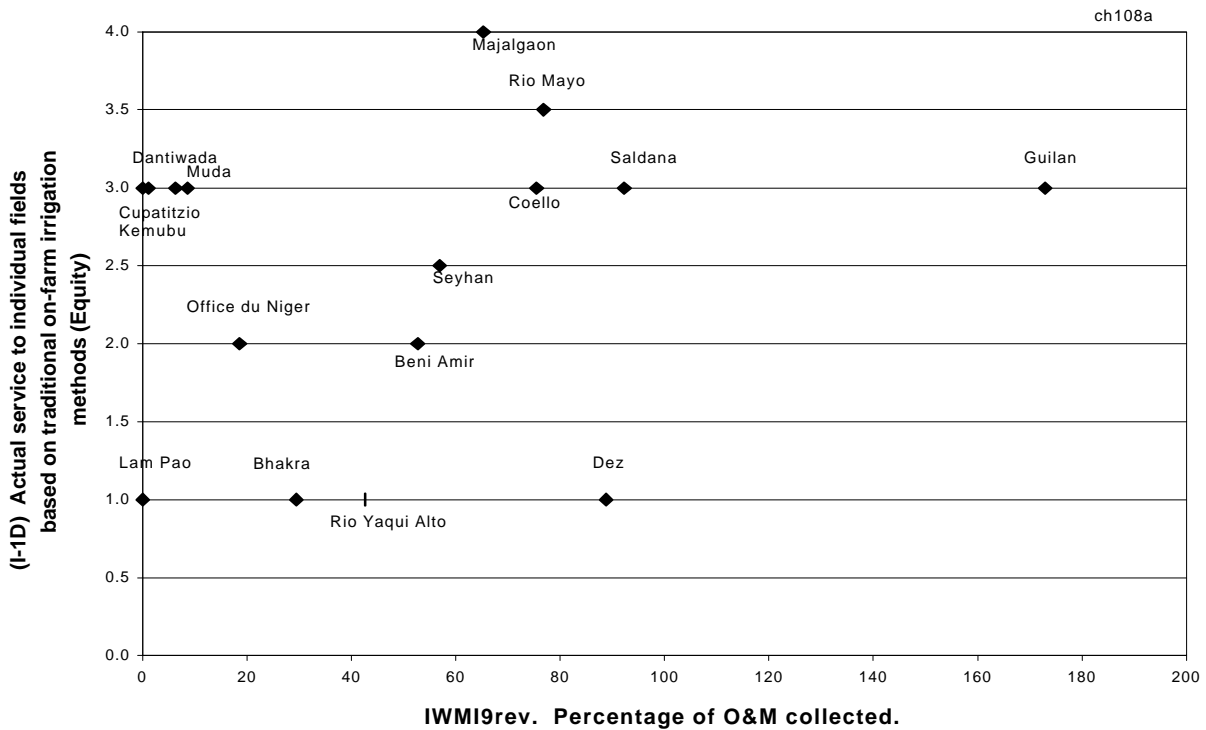


Figure 7-28. Scatter plot between [percentage of O&M collected] and the [actual service to the individual fields based on traditional irrigation methods (equity)].

Number of Turnouts Per Operator

The "number of turnouts per operator" variable is a key cause variable that correlated with numerous other indicators. The following graphs illustrate a trend of increased performance and service that is linked to an increase in the number of turnouts per operator - an extremely important point that is linked to both design and management.

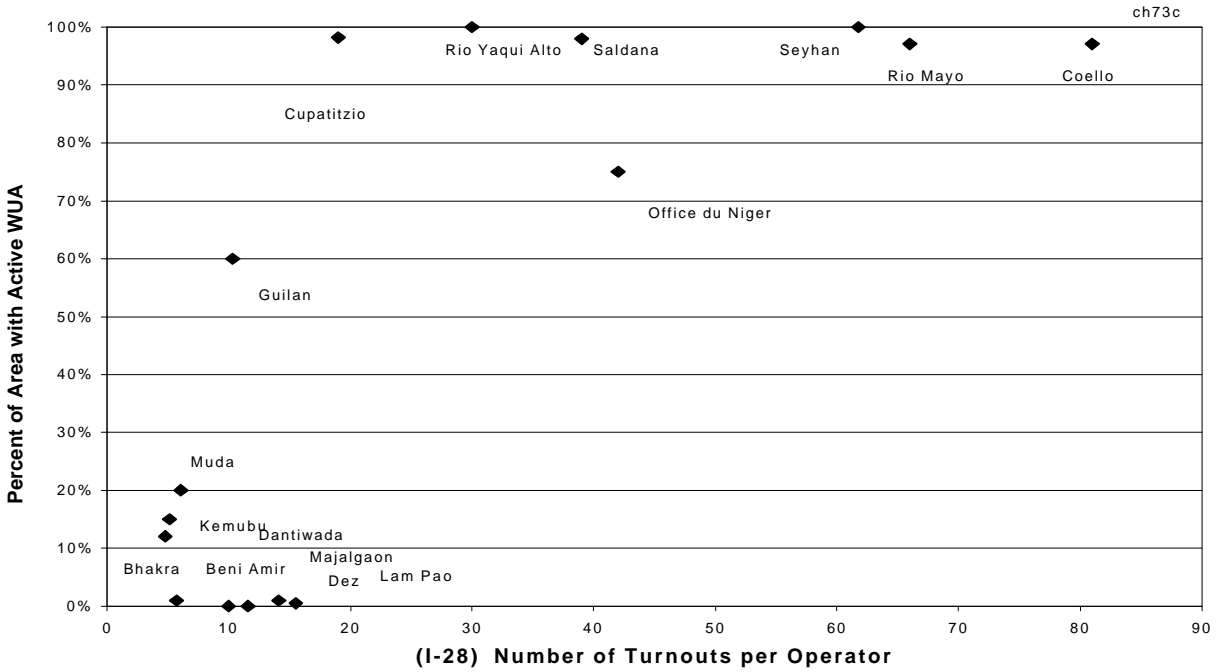


Figure 7-29. Scatter plot between [number of turnouts per operator] and the [percent of the area with an active water user association].

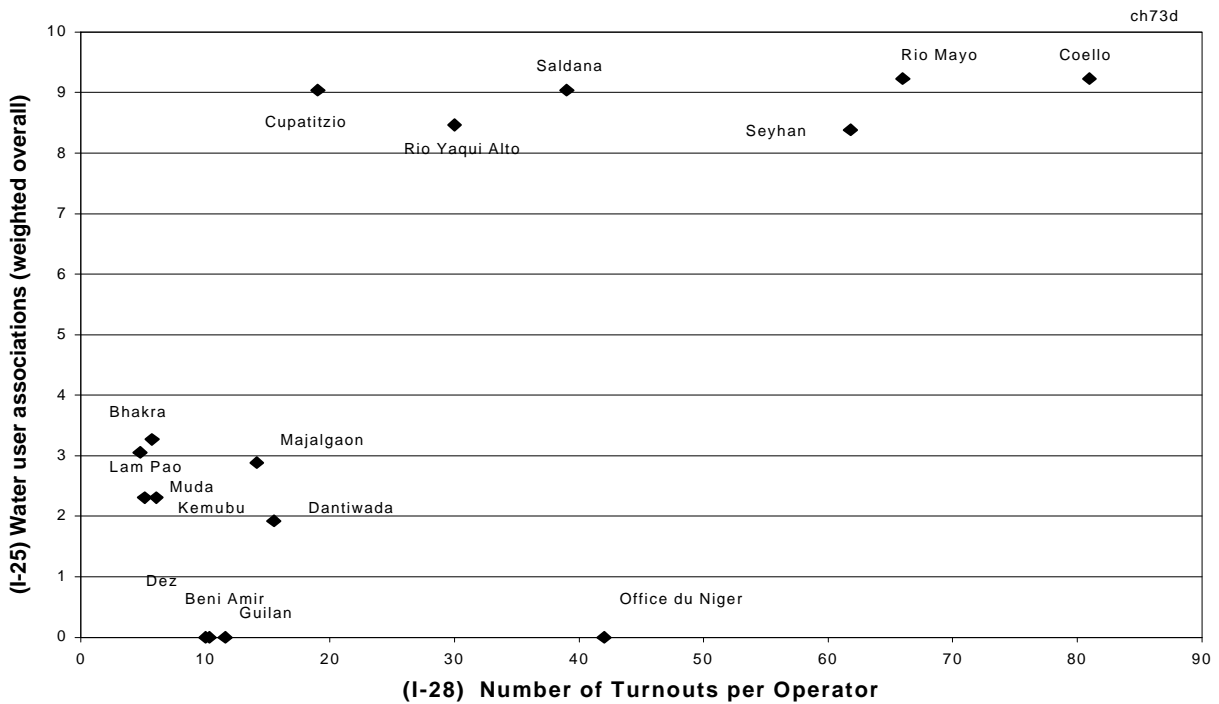


Figure 7-30. Scatter plot between [number of turnouts per operator] and the [water user associations (weighted overall)].

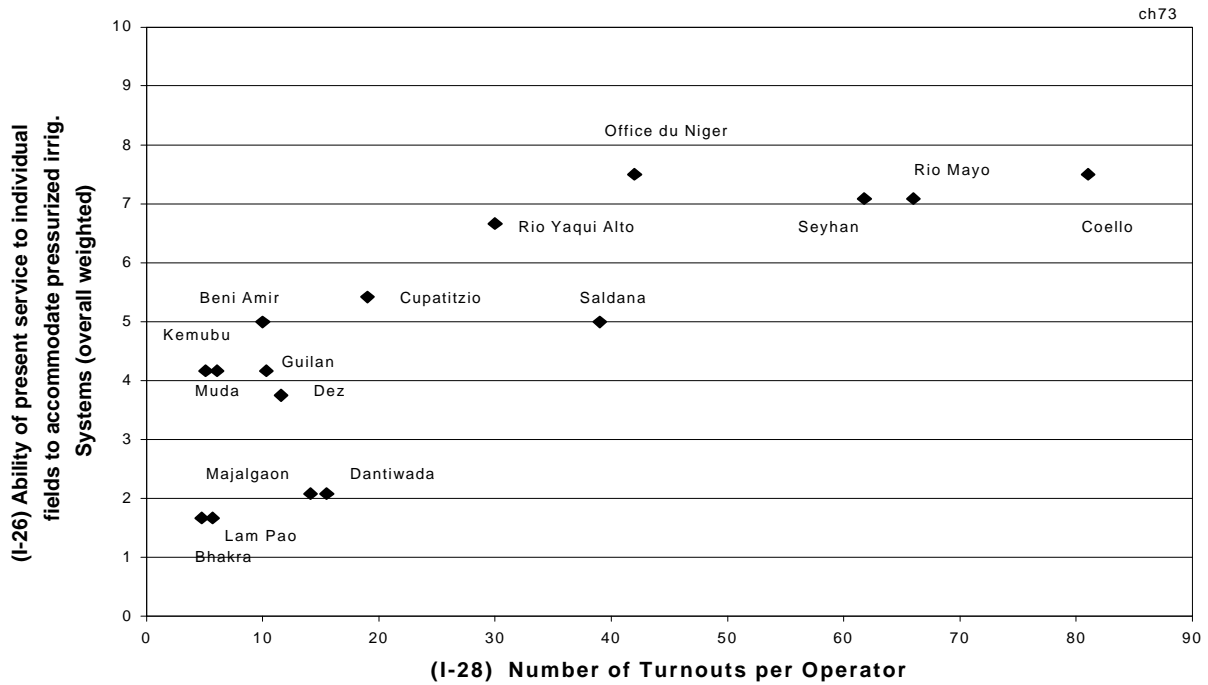


Figure 7-31. Scatter plot between [number of turnouts per operator] and the [ability of present service to individual fields to accommodate pressurized irrigation systems].

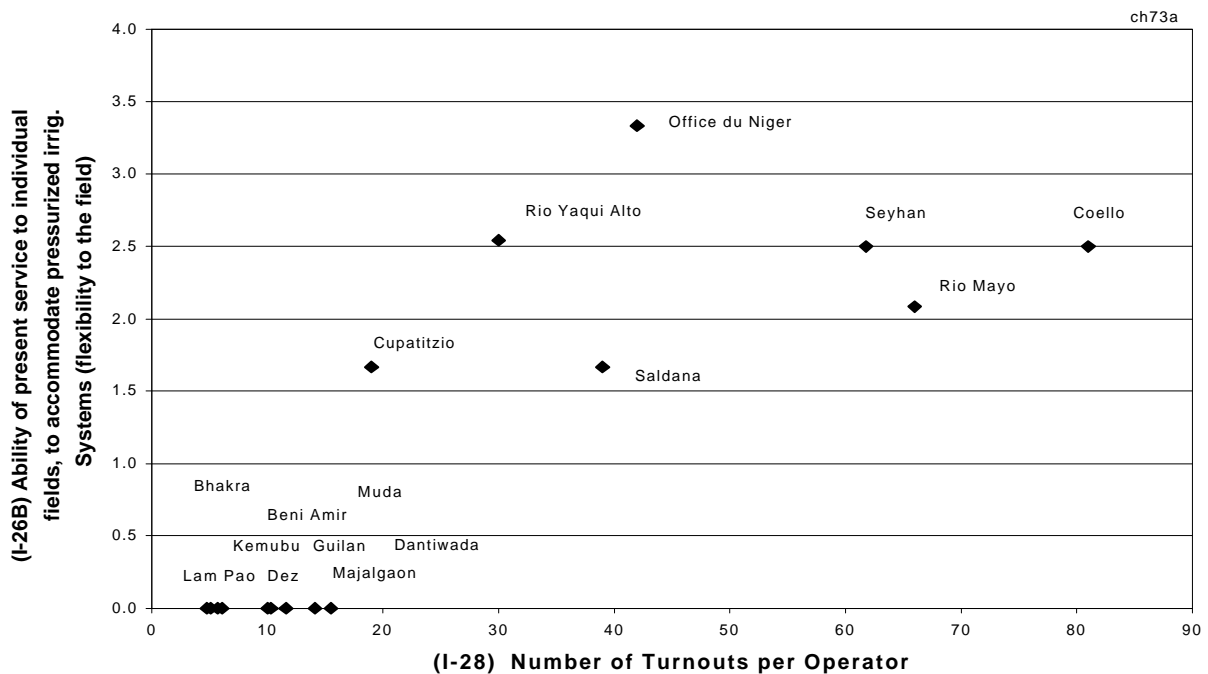


Figure 7-32. Scatter plot between [number of turnouts per operator] and the [ability of present service to individual fields to accommodate pressurized irrigation systems (flexibility to the field)].

It is clear that having additional personnel does not mean there will be a more flexible operation. When WUAs were formed in Mexico, one of the first actions was to fire a large percentage of the previous government employees and then provide the remaining operators with the means of operating efficiently. The systems with a large number of turnouts per operator seem to have several things in common. These systems tend to have operators that understand the concept of "service". The systems have staff that are mobile and spends a high percentage of time in the field working on operations rather than at the office filling out paperwork (or in the field just collecting statistical data).

The activity of the water user association also appears to be linked to the number of turnouts per operator. Projects that are overloaded with operators appear to have poor success with successful water user association formation.

Summary

There are several variables that seemed to have a strong correlation when compared to other variables collected in this research. The following are the key variables that were evaluated in this section:

- Percent of Area with an Active Water User Association
- Size of the Water User Association
- Time Needed for the Manager to Travel Down the Main Canal
- Communications - How Often do Cross-Regulator Operators Communicate with the Next Higher Level (Hr)
- Cost of the Land Close to the Head of Canals
- Actual Service to Individual Fields Based on Traditional Irrigation Methods⁵
- Actual Service by Main Canals to Its Subcanals
- Capacities
- Percentage of O&M Collected
- Number of Turnouts Per Operator

Plots were constructed to evaluate the relationships to see if there were any trends in the data. Due to the nature of this study, the evaluation consisted of finding strong visual relationships.

The following summarize some of the key findings of the graphs:

1. The projects with a high level of flexibility to the individual fields have the highest values for the percent of area with water user associations. Those projects with low water delivery service ratings seem to have a problem with getting the water user associations started.
2. The projects with a high percentage of active WUAs seem to have several things in common that contribute to the success of implementing a WUA. These systems have a high degree of flexibility in the water delivery service to the individual fields.
3. There is a link between the creation of effective WUAs and the future transition to pressurized irrigation methods.

4. Those projects where the manager has difficulty getting down the canals, the stated water delivery service to fields is the lowest.
5. Those systems with the worst access have the least expensive water.
6. Those projects that have a poor transportation network seem to have a lower level of service.
7. If the main canal is easily accessible, then the headworks to the submain canals are operated quite well.
8. Those projects with the least amount of flexibility and experiencing poor service are the ones with the most expensive land costs.
9. The projects with the best ratings for the WUAs are the projects with the lowest land costs.
10. The general trend is that there needs to be clarity and correctness in the instructions in order for projects to have good service at the turnouts to the individual fields.
11. Good service from the main canals to the submain canals is a key indicator for providing good service to the field level.
12. Some of the projects are consistently on the low end of the graphs (Lam Pao, Dez, Rio Yaqui Alto and Bhakra).
13. In general there was minimal anarchy in the evaluated systems. This is in sharp contrast to previous studies that have noted extreme chaos and anarchy in traditional irrigation projects. Instead, this research project shows relatively optimistic results.
14. There is a limited relationship between the level of service provided to the individual fields and the output of the project. None of the IWMI production based external indicators showed good correlations with any of the other variables based on the Pearson Correlation coefficient. This may be partly due to the problems with collecting meaningful economic data with the rapid appraisal process (RAP).
15. The projects with the highest efficiency are the ones with the smallest capacities. An erroneous conclusion might be that it best to design projects with a restriction in the flow rate capacities in order to force the projects to have better irrigation efficiency. At first glance, this appears to be the logical conclusion. However, project efficiency is only one measure of the performance of the system. Too much emphasis on the project efficiency can lead to incorrect design criteria.
16. There may be a relationship between a large flow rate capacity and the ease to form and sustain a water user organization.

17. A trend of increased performance and service that is linked to an increase in the number of turnouts per operator - an extremely important point that is linked to both design and management.
18. The systems with a large number of turnouts per operator seem to have several things in common. These systems tend to have operators that understand the concept of "service". The systems seem to have staff that is mobile and spends a high percentage of time in the field working on operations rather than at the office filling out paperwork (or in the field just collecting statistical data).