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METHODOLOGY FOR THE STUDY OF IRRIGATION PERFORMANCE IN ZIMBABWE

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INTRODUCTION

This project set out to measure and compare the performance of different types of irrigation systems in Zimbabwe. This research examined both large-scale and small-scale irrigation systems, but with greatest emphasis on smallholder systems under Agritex, community, and individual management. ARDA systems which include smallholders on a settler component were also included in the study.[1]

One of the major objectives of the research project was to develop and test a methodology for assessing smallholder irrigation performance in Southern Africa. The process of developing a methodology began with interdisciplinary meetings in which all researchers identified dimensions of performance to be studied and the key factors hypothesized to determine performance. Sources of information on each of the dimensions and determinants of performance (dependent and independent variables) were then identified, and data collection instruments designed to capture the information. In many cases, triangulation of measures was used assessing aspects of performance from different standpoints; for example, water measurements and farmers' opinions of water reliability.

The major strategies of data collection included:

- reconnaissance visits to each scheme;
- daily observations;
- periodic surveys of selected farmers;
- collection of secondary and scheme level data on sample schemes; and
- a postal survey of irrigation managers on all Agritex systems.

The reconnaissance visits familiarised researchers with the selected schemes, introduced the research to the system managers and farmers, provided information on infrastructure and other scheme level variables, and served as the basis for siting of hydrologic measurement points. Although the daily observations and survey methods of data collection correspond roughly to the engineering

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and socio-economic aspects of the study, respectively, the daily observational data noted some agricultural activities in addition to rainfall and water flows, the farmer surveys included detailed questions about water management practices in addition to household characteristics and irrigated production, and the postal survey dealt extensively with water management practices. Scheme level information covered irrigation and service infrastructure, prices, meteorologic data, and other data on the environment of each system. All researchers, regardless of disciplinary background, made use of data from all sources.

The present study builds upon the methodology used in prior studies of smallholder irrigation in Zimbabwe, particularly work by Rukuni (1984) and Overseas Development Institute (ODI) in conjunction with Hydraulics Research (HR) and Agritex (Tiffen 1990) on Agritex and ARDA systems, and by Loughborough University and University of Zimbabwe on *banis* (Bell, et al. Windram 1987). The previous studies in Zimbabwe relied heavily on survey data. The present study includes a larger sample of schemes that cut across system types and integrates survey data with more direct hydrologic measures. Site selection was a crucial component of the research method. Site selection aimed to reduce sampling bias and provide some scope to generalise the results beyond a few case study systems.

SITE SELECTION

Because of the emphasis in the study design on cross-sectional comparison of performance of different classes of irrigation systems, it was extremely important that the sites selected for the study be broadly representative of the respective system classes:

- community managed schemes;
- Agritex managed schemes;
- ARDA estates with smallholder settlers; and
- individually-managed schemes (principally *bani* gardens).

Dryland areas were also selected for comparison in examining the impact of irrigation.

To make field data collection manageable, the sampling universe was restricted to a subset of the country's eight provinces. Four provinces were ultimately chosen for this purpose, comprising Manicaland, Masvingo, Midlands and Mashonaland East[2]. This selection was based on considerations of travel time, the wide range of agro-ecological regions covered within a limited area, the concentration of existing irrigation schemes of all types, and the existence of unexploited potential for both small and larger-scale development.

A list of Agritex and community managed schemes, provided by Agritex and contained 74 entries, was the basis for the sampling frame for these types of systems. ARDA provided a listing of all ARDA estates. Because of the study's central concern with smallholder irrigation, the ARDA list was reduced to include only those schemes with a settler component.

Because of the very small size, the unofficial and unassisted nature of *bani* garden irrigation schemes, no comprehensive record exists for systems in this category. Sampling was thus necessarily less formal, and relied more on reconnaissance to identify potential sites, learn more about the characteristics of such systems, and finally select the systems to be studied. Sampling within each of the four classes of systems is discussed separately below. The sample is listed in Table 2.1, which also shows the major charactersitics of the sites.

SITE SELECTION BY SYSTEM TYPE

Community Managed Systems

The list obtained from Agritex was first separated into two categories based on management type:

- community managed schemes (those operated by the local community; and
- Agritex managed systems.

According to the Agritex figures, there were only eight functional community managed schemes in the country in 1985. These schemes are found mostly in natural regions III and IV and tended to be older than Agritex managed systems. These schemes have a total developed irrigated area of 322 hectares, or about one-tenth of the area served by Agritex managed schemes. They are also considerably smaller, covering an average of 35 hectares each, compared to the mean of 77 hectares for Agritex schemes. All six community managed systems in the study provinces were initially selected, but after reconnaissance, Nyanchowa was dropped because it had had no water for the past three years, and was undergoing extensive rehabilitation. Tambara was also dropped because it was operated by one extended family, rather than as a conventional community managed scheme. Bangure, one of the systems selected as a community managed system, was taken over by Agritex at farmers' request during the study period. For most classification purposes, however, Bangure is treated as a community managed system. Charandura had no water in its reservoir during the 1989/90 and 1990/91 cropping seasons. Thus, no water measurements were taken in this scheme, though full survey and scheme level data were collected.

Agritex Managed Systems

This category was further reduced by excluding the thirteen Agritex schemes identified as being abandoned, and the four schemes that were shown as "planned" in the listing. This left 46 schemes that were operational in 1988, irrigating a total area of 3,528 hectares. To provide a scientifically selected sample of these systems, those falling in Manicaland, Masvingo and Midlands, were identified, yielding a list of 28 systems. Two of these were eliminated because of possible security concerns.

The sampling frame provided basic information for each Agritex system, including location, physical environment (rainfall and natural region), age, water source, irrigation technology, area irrigated, number of tenants, and plot size distribution. Many of these characteristics were hypothesised to be important determinants of irrigation performance. Stratified sampling based on independent variables improves the efficiency of the sample, but given the small size of the sample, only a few key variables could be used. After much discussion, water source and system size were selected as stratifiers.

The remaining 26 systems were grouped separately on the basis of their water source: 14 gravity diversion and 12 systems involving some pumping. The sample was stratified in this way for several reasons. First, pumping introduces additional complexity into the technical problems of operating and maintaining the water supply system. Second, it changes the cost structure of providing irrigation service considerably. Finally, the fact that 10 of the 13 failed Agritex systems were pump schemes suggests that this factor may be an important determinant of system sustainability.

The sample was also stratified by scheme size, since size was felt to be an important indicator of both technical and organisational complexity. The two groups, gravity and pump, were therefore arranged separately into rank orders of increasing size. Every second system in each grouping was then selected, with a separate random start for each group determined by a coin toss. This yielded a sample of seven gravity systems and six pump systems of varying sizes in the three provinces. The size distribution of sample systems, defined in terms of command area, number of tenants, and the average size of irrigated plots was representative of Agritex systems. The distribution of systems across natural regions, which are based on rainfall and agricultural potential (with Natural Region I being the best, and V being the worst), is representative of irrigation in communal lands. Only one scheme, Rupangwana, in the original sample fell in Masvingo, and that was subsequently dropped because of security problems. Although provinces were used for defining the part of the country in which the study would be conducted, a representative distribution of sample sites across provinces was not seen as crucial, as long as natural regions and other potential determinants of performance were represented.

After initial reconnaissance, several schemes had to be omitted from the sample because of time and logistic considerations, but every effort was made to preserve a distribution across management types, pump and gravity systems, and natural regions. More Agritex gravity than pump systems were omitted to preserve the balance in the overall sample, and because pump systems represent the direction of most new irrigation development. An attempt was made to keep systems in which multiple water measuring devices had been installed, so that within-system hydrologic variability could be assessed. The following systems were dropped from the sample, though in many cases water measurements and baseline survey data were collected:

- Exchange was part of an intensive study by Agritex of water distribution. There was thus a high risk of respondent fatigue among farmers. It was also felt that Agritex workers on the scheme should not be asked to collect extra data for another study;

- Rupangwana and Nyamaropa involved security risks for the team going in to conduct the study;

- Mabwe Matema's reservoir did not have water during the study period;

- Nyahoni was scheduled for rehabilitation during the study period, which would have caused considerable disruption of both the water measurements and farming activities on the system; and

- Shagari is a gravity system in Natural Region III/IV, which was the most heavily represented. When resource constraints required elimination of an additional sample scheme from the survey, omitting this system preserved the most balanced overall sample. However, because water measurements were already underway, Shagari is included in the hydrologic assessment. (Conversely, Mondi Mataga was included in the survey data collection, but because of its remote location, hydrologic data were not collected at this site).

ARDA Systems

At the time the study was initiated ARDA owned and managed 22 agricultural operations in Zimbabwe, of which 17 had a significant irrigation component. The area under irrigation on these schemes totals 12,364 hectares, more than three times the area covered by Agritex schemes. The preponderant share of the water used in ARDA schemes is pumped from surface sources.

Six of the ten largest ARDA schemes have a settler component, in which smallholders work a portion of the estate land. Because of this study's primary interest in smallholder irrigated agriculture, the three schemes with settlers in the study provinces were selected for the sample. Of these, Tsovane was eliminated from the final sample for security considerations, leaving Chisumbanje and Middle Sabi. Both are pump-based schemes located on the Save river in Natural Region V, the most arid agroclimatic zone. Their combined area is 6,060 hectares, or about half of the total area under irrigation on ARDA schemes. Settlers work 887 hectares, or 14.6 percent of this area.

Bani Irrigation Systems

Clusters of irrigated *bani* gardens have not been formally recognized as irrigation systems. There are thus no registers of such systems which could serve as a sampling frame. Bell, *et al.* (1987) have estimated that irrigated gardens on *bani* landforms cover 15 to 20 thousand hectares. The procedure for selecting garden irrigation systems for this study therefore had to rely heavily on field visits and reconnaissance. Several field trips were made to identify potential sites, learn more about the characteristics of such systems, and finally select the systems to be studied. Sampling criteria included:

- Density of irrigated gardens on the *bani*. Many *banis* are predominantly used for grazing, and many have only a few scattered gardens. At least 10 gardens close together are needed to have strong hydrologic and interpersonal interaction if the *banis* are to be treated as irrigation systems. Looking at intensively cultivated *banis* gives a better understanding of the potential productivity and problems of such irrigation systems, even if many *banis* do not have such high densities and interaction among gardens and gardeners;

- Proximity to other irrigation systems in the study to ensure comparability of weather and agroclimatic resources between *bani* systems and community, Agritex, or other conventional irrigation systems in the study. There was also an explicit attempt to ensure that garden irrigation sites were not closer than other types of smallholder systems to major cities and transport links. Thus, all *bani* garden systems in the sample are 25 to 50 kilometers from asphalt roads;

- Water availability should vary between sample sites. Thus two relatively wet and two relatively dry *banis* were selected. This not only provides hydrological variability, but also affects irrigation practices. Water channels, drainage, and raised beds are more important on *banis* with water at or near the surface, while *banis* with lower water tables are more dependent on lifting water from wells. This in turn affects the use of equipment and labour inputs; and

- Stream flow should not be apparent in the cultivated area of the *banis* studied. Because farmers in these indigenous irrigation systems do not have formal water rights for irrigation, it is not legal for them to interfere with stream flow. We were anxious not to study and draw attention to systems if doing so could cause problems for the farmers with local authorities.

Initial reconnaissance trips identified garden irrigation systems in the area near Charandura-Bangure, Mwerahari-Sachipiri, and Mkoba-Shagari irrigation systems, and in the Mutoko area in Mashonaland East. The Mutoko area is noted for intensive cultivation of *banis*.

The *banis* visited around Charandura-Bangure had a low density of gardens, and hence were not suitable as sample sites. Several intensively cultivated systems with complex interaction between gardens were identified in the vicinity of Mkoba-Shagari irrigation systems. Two of these *bani* systems (one wet and one relatively dry site) were selected for study. One other relatively dry site was selected in the Chivhu area around Mwerahari-Sachipiri, and one highly productive and intensively cultivated site in the Mutoko area of Mashonaland East was selected. Subsequent inspection of aerial photographs and greater familiarity with the area confirmed that these were representative *bani* irrigation sites.

Dryland Sites

In addition to the irrigation systems, the study also collected baseline and production survey data from dryland agriculture. This allows comparison of agronomic and economic performance of irrigation schemes with unirrigated cultivation. For the dryland comparisons to be most effective, sites were selected which are similar to the irrigation systems in terms of agroclimatic region and access to infrastructure.

To make most effective use of resources, two dryland sites were selected, each near a cluster of sample irrigation schemes. One was near Charandura in the relatively high potential Natural Region III, similar to many of the sample irrigation systems in Midlands. The second dryland sample was near Chakowa in the drier, low potential Natural Region V in the Save Valley of Manicaland. While the dryland sites do not provide a full control group for each irrigation scheme, they can be compared to clusters of irrigation systems in the study.

HYDROLOGIC DATA COLLECTION

Daily measurements of water flows and rainfall were recorded on sample irrigation systems for the 1990/91 crop year. These were supplemented with observations on area irrigated, cropping activities, and problems encountered. The data were used to calculate water balances, estimate crop water requirements, and to develop indicators of hydrologic performance, including adequacy, timeliness, and efficiency.

Hydraulic Measurements on Community and Agritex Managed Systems.

A total of 46 measuring devices were installed at strategic points in the twelve community and Agritex systems which were monitored. On small schemes only one measuring point was installed, but on larger or more complex systems, where distinct blocks could be identified, there were multiple measuring points. This allows comparison of water deliveries and development of equity measures for water distribution to blocks within schemes.

Locally manufactured cut-throat flumes were installed in the concrete lined canal beds at most measuring points. These were calibrated and cross-checked using current meters. V-notch weirs initially installed on Shagari proved unacceptable, because debris trapped behind the notches led to incorrect readings, and water backed up behind the notch gave farmers the impression that the structures were interfering with the water supply, and thus led to vandalism of the structures. Pump operation logs maintained by the pump operator employed by the then Ministry of Energy and Water Resources Development (MEWRD)[3] were also reviewed.

Agritex staff on the schemes were trained to read the flumes and enter the data on booking sheets three times a day. Automatic recording devices, which had been used in the Nyanyadzi study, were not used here because of their high cost and susceptibility to vandalism in remote areas.

Hydrologic data collection began during the 1990 winter season. Initial problems in making readings were monitored and corrected, and final data collection was conducted for the 1990/91 summer and 1991 winter season. This corresponds with the data collection period for the seasonal production surveys on the sample schemes. Hydrologic data collection was continued through summer 1991/92 on a number of the systems. This captures many hydrologic effects of the severe drought of 1991/92, though production data are not available for the additional season.

Hydrologic Measurements on Bani Garden Systems

Water measurement on *bani* sites was somewhat more complex because much of the water cannot be measured in surface channel flows. Subsurface water levels were monitored in observation wells at a number of locations on each *bani*. In Dufuya, where it was possible to measure surface flows, water levels were measured under a culvert and in a flume. Estimates of water applied by lifting from wells were estimated from bi-weekly recall of farmers' estimates of time spent irrigating from wells. A sample of 141 irrigators (men, women, and children, distributed among all four *bani* sites) was then observed irrigating from wells to count the number of buckets lifted, and calculate the amount of water applied per hour.[4]

Because there were no local Agritex staff responsible for *bani* systems, local people were employed to take water measurements, meteorologic observations of rainfall, open pan evaporation and temperature, and to observe other aspects of *bani* land and water use. These data also cover the 1990/91 summer and 1991 winter cropping seasons.

Hydrologic Measurements on ARDA Systems

ARDA systems maintain their own water measurements at each pumping station. The project proposed to make use of these records, rather than making another set of daily water measurements on the Middle Sabi and Chisumbanje irrigation systems.

SURVEY DATA COLLECTION

Four rounds of surveys were conducted on the sample sites, namely:

- a baseline survey;
- a water management survey, and;
- one production survey for each of the two seasons in the cropping year: summer 1990/91 and winter 1991.

The baseline survey concentrated on household and farm characteristics and dependence on irrigation. The water management survey asked about particular practices, problems, and opinions about the irrigation system. Each seasonal survey dealt with inputs (including water and labour) and output from all crops on irrigated plots in that season.

Sample Farmer Selection

In developing a sampling methodology to select farmers to participate in the surveys, it was important that all farmers on the irrigation schemes be able to understand why some were to be interviewed and others not. Without this, there is the possibility for excluded farmers to feel slighted or selected farmers to feel imposed upon. Agency staff should also be able to understand the objectives of the study and the sampling methodology so they do not try to have the scheme represented by only "good" farmers.

To improve this understanding, the team held a meeting with the extension worker and farmers to explain the project and solicit cooperation at each sample site. The sampling methodology was explained and the sample itself selected at this initial meeting. It was therefore important that the sampling methodology not only avoid potential biases, but that it be easy to understand and carry out in the field.

The tenants' register which is maintained at all formal irrigation systems was used as the sampling frame for selecting sample farmers on community, Agritex, and ARDA sites. If a scheme had up to 20 farmers, all were included in the surveys. For schemes with 21 to 80 farmers, a simple random sample of 20 farmers was selected by copying all names from the tenants' register (eliminating all duplicate names of those who have more than one plot), and drawing out the slips of paper. For schemes with over 80 tenants, the names were stratified first by sex, then listed in alphabetic order. If there were 80 to 120 farmers a random number between one and four was drawn to select the first name, then every fourth farmer on the list was selected. If there were 121 to 200 farmers, a random number between one and five was drawn for the first name, and every 5th name selected. For over 200 farmers, every 7th farmer was similarly selected. Such simple random or stratified systematic samples with a random start are readily understandable, and were accepted by farmers and scheme staff.

The different sampling fractions depending on number of farmers on schemes represents a compromise between the need for a high sampling fraction to provide a minimum sample size on the smallest systems, and resource constraints which precluded use of a high sampling fraction on schemes with hundreds of farmers. Appropriate sampling weights are used in the analysis to account for this.

Because *bani* and dryland sites lack a formal tenants' register, the sampling frame and methodology was modified. A sampling frame was developed for the *bani* sites by mapping all gardens and obtaining the names of all garden holders. Farmers were then selected by the same procedure as in other irrigation systems. All garden holders were included in Mushimbo and Maboleni. Mbiru had a random sample of 21 out of 57 farmers. The size and hydrologic complexity of Dufuya was dealt with by dividing the area into four quadrants (with the stream in the middle and the midpoint on the slope as dividing lines). The list was stratified by quadrant of garden location, then alphabetized, before drawing a systematic sample with a random start. Two additional gardeners, whose wells were used to monitor water levels, were also included in the sample.

For each dryland sample site, a group of two to three adjoining villages was identified and visited to ensure that the soils and rainfall were comparable to the nearby irrigation systems. With the help of the dryland Agritex extension worker for those villages, project enumerators carried out a census of all farmers in the villages to gather basic information on amount of dryland and irrigated holdings, and whether the household was actively involved in agriculture. Those households not actively involved in agriculture, and those with plots on an irrigation scheme were dropped from the list before sample selection, to ensure that the sample respondents were dependent on dryland cultivation. Those with small garden plots were not excluded, as many of the dryland farmers in Natural Region III are likely to have a garden.

Of the remaining farmers on the list, a random sample of twenty farmers per cluster was selected. These farmers were interviewed with the baseline survey and the production survey for the summer season. The water management and the winter production surveys were not administered to these farmers because they are not able to cultivate an unirrigated crop during the dry winter season.

Survey Methodology

Survey questionnaires were developed to collect information about irrigation practices and production relevant to each type of system yet comparable across system types in the overall study. One baseline survey was designed to cover household assets and characteristics on community, Agritex, and ARDA systems. It included questions on household food security and sales to neighbouring dryland farmers, as well as diseases associated with irrigation. This survey was then modified for the dryland and *bani* sites. Water management surveys had to be adapted to the irrigation technologies used; one questionnaire for the community, Agritex, and ARDA schemes, and one for the *banis*. No water management survey was administered to the dryland sample.

The seasonal production survey was directly applicable across all system types, and for both summer and winter seasons. The seasonal survey collected data on inputs, outputs and marketing of each crop on each irrigated plot. Full details on use and hire of labour and equipment was collected for all crops on the first plot only. Irrigated farmers were only asked cropping pattern information from their dryland holdings, but full dryland production details were asked of the dryland sample farmers.

A team of four enumerators plus one researcher administered the survey at all community, Agritex, *bani* and dryland sites. A resident enumerator was responsible for collecting the surveys in the two ARDA systems. The use of a common team for all surveys meant that not all surveys were conducted at the same time across systems, but made most effective use of trained manpower and logistic resources and provided continuity of technique.

The baseline survey was conducted before the 1990/91 summer season, the water management survey during the summer season, and the two seasonal surveys were conducted after the seasons were over. While recall of production details is difficult over a full season, the quality of information was generally good for crops with a single planting and harvest period, but more problematic for horticultural crops which have multiple harvests.

Extension workers at each site were asked to rate each sample farmers' expertise with irrigation on a five-point scale (from "Excellent" to "Very Poor"). This provides one indicator of management capacity, as a supplement to information on farmers' formal training and experience (from the baseline) and knowledge of irrigation practices (from the water management survey).

Staff on all community managed and Agritex systems in the country were sent a postal survey to identify water management practices, problems, and ideas for improvement. This survey parallels the farmer water management survey in many regards, but provides a different perspective (that of system managers, rather than users), and covers all provinces and systems in the country, not only those in the sample.

SCHEME LEVEL INFORMATION

Many of the factors hypothesized to be determinants of irrigation performance apply to the system level, rather than the farm level. These include system size, age, condition of facilities, access to infrastructure, prices, and other aspects of the policy environment. Resident field staff measured and recorded those system level features which change rapidly (e.g. rainfall) on daily observation sheets, but other features which change slowly (if at all) were collected on special data sheets filled in by Agritex staff or project researchers on a one-time basis.

Secondary data relating to irrigation policy, such as price series or meteorologic records, were collected by University of Zimbabwe students. While much information exists on irrigation systems and irrigated production, locating the records and coordinating this data with the hydrologic and survey data required considerable time and attention.

CONCLUSION

Much research effort on this project went into developing a methodology for comparative assessment of irrigation system performance in Zimbabwe, in addition to the effort of collecting and analyzing the data. The study cut across disciplinary boundaries in measuring performance, in identifying factors which affect performance, and in collecting and analysing data. In operationalising such an inter-disciplinary approach, considerable effort was made to ensure that all relevant determinants of performance were discussed and indicators devised and that the data for each indicator were collected, recorded, entered in a computer, and made available to all participating researchers.

The methodology and data collection instruments were designed with considerable flexibility so that they can be applied to different types of irrigation systems. While some modification of the hydrologic measurements and water management surveys are required to accommodate the specific technology and other characteristics of different scheme types, the methodology is broadly applicable to smallholder irrigation in Zimbabwe. The study could thus be replicated on other irrigation schemes or *bani* irrigated areas in Zimbabwe, and, most likely, with some modification in other parts of the SADC region as well. For example, Malawi's irrigated sector is composed of commercial estates, government-run smallholder schemes, self-help schemes (comparable to Zimbabwe's community schemes), and garden irrigation on *bani* wetlands. Chisenga (1993) draws attention to the need for an overall irrigation development strategy, and particularly for evaluation of the trade-offs between different types of systems. The methodology developed in this research study lends itself to such an evaluation by integrating the technical, agro-economic, and social aspects of irrigation performance, and providing a comparable way to study different types of irrigation systems, including both formal, government or farmer managed systems and informal *bani* garden cultivation.

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NOTES

1. Original plans to collect some data on large-scale commercial systems were complicated by sensitivities regarding the government policy towards land redistribution. Several meetings were held with the Commercial Farmers' Union to discuss the project and the issues facing commercial irrigation systems. Project researchers visited two commercial systems and interviewed the farmers, but were not able to collect formal data on water deliveries, crop production, or economic returns. It was therefore not possible to include commercial systems among the study sample for more detailed comparisons.

2. Mashonaland East was selected only for bani sites.

3. The Department of Water Development is now under the Ministry of Lands Agriculture and Water Development.

4. Initial plans to compute separate water lifting rates for men, women, and children did not work out because there was more variability within each category than between men, women and children. The amount of water applied per hour depends considerably on how irrigating is combined with other activities such as child care, weeding, picking vegetables, or general garden maintenance.