STRIVER TECHNICAL BRIEF

Strategy and methodology for improved IWRM
- An integrated interdisciplinary assessment in four twinning river basins

TB No. 3

Alternative approaches to valuing irrigation water

A survey of farmers in Tungabhadra Basin, India, shows large variation in the price of water in informal irrigation markets, in farm returns to increasing irrigation, and in implicit willingness to pay for water in hypothetical water pricing schemes. The large variation in water accessibility and farm socio-economic conditions poses a challenge for uniform water pricing policies.

The STRIVER Technical Brief series summarizes results from the EC FP6-funded STRIVER project aimed at an applied research audience and water managers

Alternative approaches to valuing irrigation water

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The brief discusses the challenges in using survey-based methods of economic valuation of water. Three different approaches to economic valuation of irrigation water are compared based on data from a farmer survey conducted in Tungabhadra sub basin. Prices reported by farmers for sale and purchase of an additional irrigation are of the same order as willingness to pay estimates derived from a choice experiment. Because of small number of water trades there is large variation in market-price based estimates. Financial returns to a given crop as a function of irrigation frequency report values that are both lower (for rice) and higher (for Arecaunut) than choice experiment estimates. Again, large variation in irrigation frequency and profitability across farms make conclusions on convergent validity difficult. Financial returns to a crop as a function of volumetric water use faces large uncertainties in terms of the calculation of water volume. Photo cover: David N. Barton

References

This STRIVER Technical Brief is based on the following research reports and scientific literature:

Griffin, R.C. (2006) Water Resource Economics. The Analysis of Scarcity, Policies and Projects. MIT Press, Cambridge.

Fact box

Economists use different techniques for estimating the economic value on water. “Stated preference” methods, such as choice experiments, use farmers’ choices between the present situation and hypothetical alternative water management policies, to estimate willingness to pay for characteristics of that policy, such as more frequent irrigations. “Residual imputation” uses data on crop yields, crop prices, input costs and how much water is actually used, to estimate an average value associated with water as an input. “Production function” approaches calculate the marginal contribution of each input to farm profits using multivariate techniques. “Market prices” take the selling/purchasing price of water is taken as an indicator of the value of foregone/additional water in crop production. A study of convergent validity compares these different estimates.

Study design

A survey was conducted in February-March 2008 with interviews of 216 farmers in the Bhadra command area and an equal number in the Tungabhadra command area downstream, for a total sample of 432 households. The survey was used to record farm characteristics including cropping patterns, crop yield, farm labour and agricultural inputs by crop type, and monthly water use practices in the 12 month before the survey. Tungabhadra Left Bank Canal is predominantly rice) compared to Bhadra Right Bank Canal (average main crop parcel size of 2.8 acres versus 0.75 acres respectively). All Arecaunut cultivation in the survey is located in the Bhadra upstream area.

Farmers were also asked whether they had bought or sold irrigation water in the previous year, the number of irrigations and the purchase or sale price of each irrigation. Finally, a choice experiment was conducted where farmers were asked to choose between alternative water management regimes which included different combinations of prices per irrigation and per acre, monthly water availability, irrigation frequency per month and water sharing. The data collected in the survey aimed at comparing valuation estimates for irrigation; (i) average water trading prices, (ii) average residual value imputed to water from the farm profit function, (iii) marginal value computed using the marginal contribution of water to crop yield, and finally (iii) implicit willingness to pay derived from the choice experiment. The aim was to study whether values were similar (so-called convergent validity). Economic theory expects the valuation estimates to converge with increasing possibilities to trade water.

Given the lack of irrigation water consumption monitoring at farm level, and water scarcity particularly in the Tungabhadra command area, there is a poor basis for water trading. Only about 12% of the sample had purchased or sold water in the previous year. Another limitation was incomplete data regarding farm crop yields, inputs and prices. In the survey setting, only 47% of the sample provided complete farm input-output data that made it possible to calculate water value using methods (ii) and (iii) above.

This technical brief illustrates the limitations of using survey-based or “snap-shots” of the water use situation of farmers. The total sample size was planned with a stated preference valuation technique in mind – it was sufficient to obtain significant and meaningful results for the choice experiment. However, our experience shows that sample size would have to be several times larger to collect sufficient data to use the production function approach to water valuation. The alternative to a representative survey is in depth time-series studies of representative farm types. The short time-span of the STRIVER research project did not allow for such a longitudinal approach.

Estimating water volumes

Given the lacking monitoring data on water consumption a lot of emphasis was placed on asking the farmer to recall monthly water use.

Estimating water use based on canal profiles, watering times and frequences.

Photo: Mai Simonsen

Farmers were asked about the physical dimensions of farm level irrigation canals, watering frequencies, and average number of hours per watering per month. Farm channel profiles were used with assumptions about channel slope and roughness coefficients in Manning's formula for gravitational channel flow velocity. Given that surveys did not record actual farm channel characteristics, we used sensitivity analysis on slope and roughness coefficients from the literature to estimate a range of likely flow rates for each farm. The aim was to evaluate whether this water use "recall" data could be used to calculate the volumetric value of water in the absence of monitoring data. Variation in water use between farms is driven by the differences in irrigation channel profile, water times per irrigation and irrigations per month in the dry season. The variation between farms in estimated water intensity is illustrated in Figures 1.1 and 1.2.

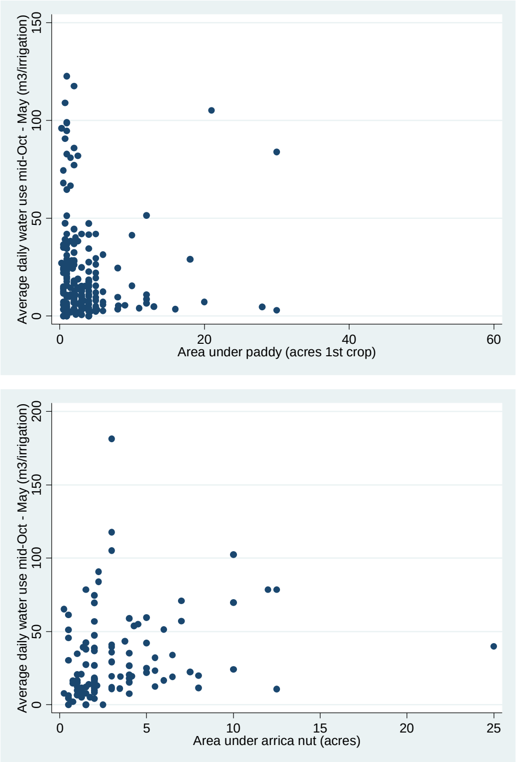

Figure 1.1-1.2 Variation in water use per irrigation for rice and Arecaunut

Figures 1.1-1.2 illustrate the measurement problems in estimating water volume used. Water used per irrigation varies enormously, even for farms of the same size. There is some indication of falling volumetric water use per irrigation in large rice farms, but it is not significant. For Arecaunut there is a somewhat clearer tendency of increasing water volume per irrigation, indicating that larger farms have larger irrigation canals and longer hours of water availability than smaller farms.

The data appears to be a poor basis for the imputed and production function methods. We return to these methods further below. For want of a more accurate measure we will therefore compare estimated values per irrigation across the different methods.

Value based on water trading

A less data intensive method is using water trading prices as a basis for the economic value of water. The assumption behind this method is that water trades are only influenced by price, and not limited by irrigation infrastructure. In fact water trading in Tungabhadra is currently only conducted between neighbouring farmers and only to a small extent.

A water pump Tungabhadra River.
Photo : Mai Simonsen

We only have 9 observations of farmers who had conducted water sales, all from the Bhadra command, and only 42 observations of water purchases (60% from Bhadra, 40% from Tungabhadra). The data is too scarce to determine the characteristics of buyers versus purchasers. It appears that water trading is more common in Bhadra where it is more abundant. Figure 2 shows water trading prices recalled by farmers.

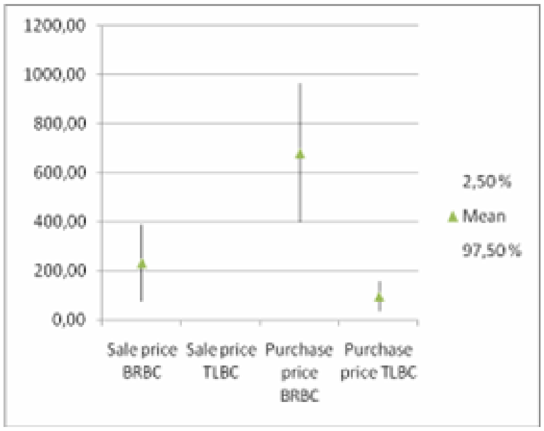

Figure 2. Average water trading prices in Tungabhadra Left Bank Canal and Bhadra Right Bank Canal

Water purchase price in Bhadra is not significantly different for rice and Arecaunut (not shown).   An unexpected result is that purchase prices for an irrigation are significantly higher than sales prices in the Bhadra command area (this is true for the same farm type, e.g. rice, not shown).   One explanation is that sampling was not representative and that sales data comes predominantly from head end farms and purchase data comes mainly from tail end locations. Multivariate analysis indicated that purchase price increases significantly with distance from the head end of the main distribution channel (but sales price showed no such significant relationship to distance). This is as expected by theory. On the other hand, water purchase price also significantly increases with the number of borewells owned by the purchaser. This is not expected given that a larger number of borewells would indicate less water scarcity at the farm level and lower willingness to pay. However, number of borewells is also an indication of larger wealthier farms with higher ability to pay (but this is conjecture given the small sample size).

An alternative explanation is that farmers will overstate purchase prices and understate sales prices if water trading is considered an unethical practice locally (this is also conjecture given that we have no parallel studies on water use culture).

Imputed residual value

Another simple approach to valuing water is to impute or assign net profits to water as an input, after subtracting from crop income all the cost of all agricultural inputs except water. This method assumes that water is the critical input for production, so that all residual profit is lost if water input is absent (reflecting water's opportunity cost or economic value). The method is susceptible to large variations in profitability between crop types and farm sizes.

Estimating financial returns to water based on yield and input costs.   Photo: Mai Simonsen

Figure 3 shows residual return to water for rice farms with different water use intensity in the dry season (mid Oct. – May).

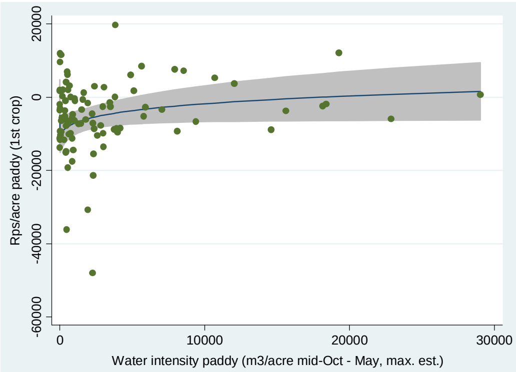

Figure 3. Financial returns to paddy rice per acre for increasing water use intensity

The 95% confidence interval for net returns *per rice irrigation* in the dry season is from -459 to 61 Rs/irrigation. Figure 3 shows very large variation in residual return to water (Rs/acre) for farms with the same water use intensity (M3/acre). There is a weak tendency to increasing average returns, but with decreasing marginal returns to water use. This is a picture that would be expected in a water scarce area such as Tungabhadra.

Figure 4 shows the same relationship for Arecaunut. The 95% confidence interval for residual returns per Arecaunut *per irrigation* in dry season is from 3780 to 7640 Rs/irrigation.

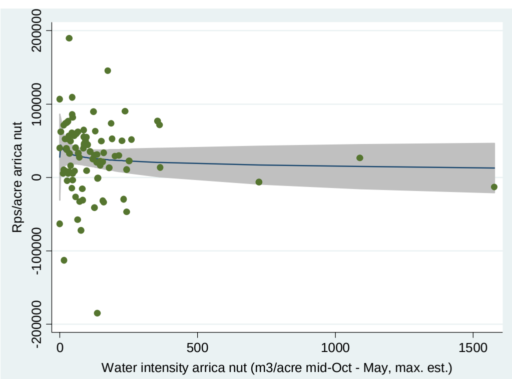

Figure 4. Financial returns to Arecaunut per acre for increasing water use intensity

There is also great variation in residual returns to water at low levels of water use intensity. However, average returns to water fall somewhat with increasing water intensity, tapering off to zero.) This is a picture that would be expected in a water abundant area where most farms were overwatering crops.

Marginal productivity value

With a cross-section data set covering a variety of farm types, there is a possibility to estimate the marginal return to increasing water use intensity. This marginal approach is preferred by economic theory, because it allows planners to identify prices that optimize aggregate welfare of buyers and sellers in a water market.

Optimal pricing theory is based on the assumption that returns to each new m^3 water use decline with increasing water use. We would expect to see average farm returns per acre increase with water intensity, but at a decreasing rate. At some point due e.g. to water logging, higher watering intensity would lead to falling average returns. We perhaps see an indication of this in Figures 3 and 4. Both the rice and Arecaunut data provides some support for using a production function approach. However, the variation in residual returns to water is very large. The larger the variation, the larger the required sample in order to estimate multivariate production functions. We only have a complete set of data on crop yield and inputs for less than 100 farms for rice and Arecaunut. In practice, it is difficult to obtain significant results on the marginal productivity of water from such limited data.

Our experience is that obtaining accurate farm agronomic data is more demanding than obtaining stated preference data. Stated preference and revealed preference valuation methods therefore require different population sampling intensities.

Implicit willingness to pay

A detailed discussion of choice experiments as a new approach to irrigation water valuation is discussed in a separate Technical Brief. The choice experiment method is based on farmers choosing, in our study, between two hypothetical scenarios combining an increase in water price, availability, irrigation frequency and water sharing, versus their current situation with no change in price and water regime. Implicit willingness to pay (IWTP) for availability, irrigation frequency and sharing is calculated based on the choices made by farmers.

Estimating implicit willingness to pay for irrigation based on preferences stated preference. Photo: Mai Simonsen

Figure 5 shows some differences in implicit willingness to pay between the two command areas and between rice and Arecaunut. IWTP for an additional irrigation is significantly higher in Tungabhadra than Bhadra and higher for rice than Arecaunut. Looking at implicit willingness to pay for sharing one irrigation, we get the opposite picture (Figure 6). The opportunity cost of foregoing one irrigation is higher in Bhadra than Tungabhadra.

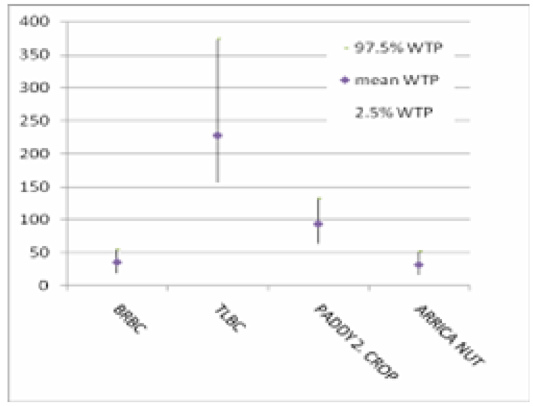

Figure 5. Implicit willingness to pay for an additional irrigation per month in Rabi season

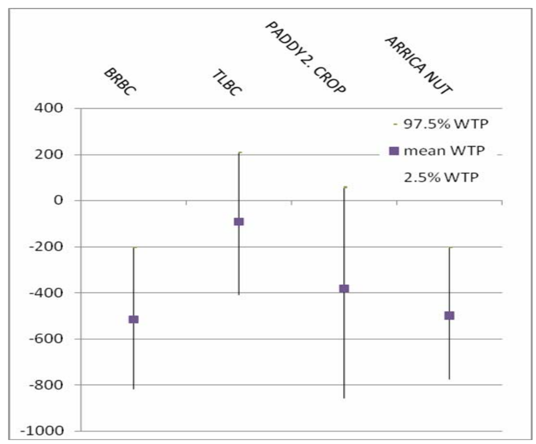

Figure 6. Implicit willingness to pay for foregoing one irrigation per month to water sharing in Rabi season

Comparing methods

Regarding the values derived from the different methods we can draw the following conclusion. <u>Arecaunut and Bhadra command area</u>: the value imputed to water from residual profit is higher than market value of water, which in turn is higher than the choice experiment estimate for an additional irrigation. The value of a foregone irrigation from the choice experiment is similar to the market price range. <u>Rice and Tungabhadra command area</u>: the value imputed to water from residual profit is lowest for this unprofitable crop, the purchase price of one irrigation in Tungabhadra is lower than the choice experiment estimate for an additional irrigation.

Broadly speaking the choice experiment *overvalues* water relative to its financial return to unprofitable and more water intensive crops in a water scarce area (rice in Tungabhadra). The choice experiment *undervalues* water relative to its financial return to profitable and less water intensive crop in a water abundant area(Arecaunut in Bhadra). There is a large variation in purchase and selling price of irrigation across the study area. This heterogeneity is also reflected in the choice experiment estimates. However, with a larger sample size with complete data in the choice experiment, we are still able to draw some policy significant conclusions on different farms types' willingness to pay higher irrigation prices.

While the sample sizes for water trading data (42 observations of purchases) and financial returns (94 observations on Arecaunut, 97 on rice) were fewer than the choice experiment, the differences between estimates was often significant. That raises questions about what to do when estimates do not converge. Can we use these methods as a basis for fixing the absolute level of irrigation water prices? Which method should we choose?

What is useful about the studies is to show the large variation in profitability across crops and locations (imputed residual value method), as well as significant farm characteristics that make farmers more or less likely to support a water price reform (choice experiment method). The results are more reliable when comparing the relative values for a given method between groups of respondents, than when comparing absolute water values across methods. The significant variation in implicit willingness to pay for irrigation water also indicates that uniform pricing schemes will create resistance within a single command area, as well as across command areas in a River Basin, because of the large differences in access to water.

Given the paucity of measured water consumption data and water trading prices in agriculture, data was collected using a survey. The weakness of this data also arises from farmers' limited ability or willingness in an interview to recall water trading prices and quantify the inputs to crop production. Because of these challenges, less than half of the farmers provided complete production function data. The choice experiment method, while based on hypothetical policy questions, does not suffer from such "recall" limitations.

February in Distributary no 54. Tungabhadra Left Bank Canal Photo: David N. Barton

With the sample size, survey length and interview quality of the present study, economic valuation results from the choice experiment method conformed most closely to expectations of economic theory. With a larger sample size the production function approach may have been possible. A general strength of the survey or "snap shot" approach is *representation*, while a general weakness is *causality explanation*. Participatory observation methods would therefore have been an important complement to the valuation methods.

STRIVER

The STRIVER Policy and Technical Brief series translate the results from the project into practical and useful information for policy makers and water managers.

The Briefs are also available online: www.striver.no

About STRIVER

STRIVER- Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins is a three year EC funded project 2006-2009 under the 6th framework programme (FP6) coordinated jointly by Bioforsk and NIVA. The point of departure for STRIVER is the lack of clear methodologies and problems in operationalisation of Integrated Water Resource Management (IWRM) as pointed out by both the scientific and management communities.13 partners from 9 countries participate as contractual partners in addition to an external advisory board.

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Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins (STRIVER)

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