Estimating area reached through irrigation as a service systems

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30 January 2023

An addendum to *"Current state of irrigation-as-a-service for smallholder farmers in Rwanda"*, N. Akaliza *et al.*, 2023

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An important question to consider is the current extent to which entrepreneurial irrigation as a service (IAAS) schemes have increased irrigated area in Rwanda. We present a simple method to estimate lower and upper bounds of the ability of IAAS to increase irrigated area, under reasonable assumptions. The method is broadly applicable.

Estimation is complicated because, as a starting point, we know neither the total number of small irrigation pumps in use nor the total irrigated area. The Government of Rwanda reports the area that is planned to be irrigated by the owners of pumps purchased under the Small-Scale Irrigation Technology (SSIT) program in each year. For example, government data report that 828 hectares were planned to be irrigated via the SSIT program in the period 2015-2018 in Bugesera District. For the same time interval, 1,030 hectares were reported as planned to be irrigated in Nyagatare District. These estimates do not include pumps that are purchased outside of the SSIT program i.e. without a subsidy. By definition, areas irrigated by rented pumps also fall outside of the government statistics.

Assumptions and parameters needed

Nonetheless, with additional assumptions, we can provide some bounds on potential additional area reached through irrigation as a service. For simplicity we assume that all pumps are functionally the same and that owners and renters use pumps the same way on their land. We do not consider the situation where owners irrigate fully and renters irrigate supplementally. This assumption is conservative: to the extent that pump renters irrigate at lower intensities than pump owners, total irrigated area will be larger than our estimates. Operationally, the assumption means that each pump irrigates the same amount of land per unit time that it is operating.

Several parameters are needed for the analysis. We assume that there are N total pumps in the region of interest. The total area *of their own land* that pump owners irrigate is given by A. We define the proportion of pumps rented in the region, between 0 and 1, as θ. For those owners who rent their pumps, we assume that they rent for an average of η days per week. We use a one week period as the basis for our analysis, under the assumption that many irrigation scheduling decisions are undertaken weekly.

The final parameter needed is the asset utilization rate, β, defined here as the proportion of available irrigation time that the N pumps must be operated in order to irrigate the owners' area A. A value of β of 1 means that all N pumps must be operated all of the

time *that they are not rented* in order to irrigate the owners' land. A β value of 0.5 means that the set of N pumps can irrigate the area A if they operate during half the time that they are not rented.

Estimating irrigation capacity

The basic unit of analysis is the *pump-day*, defined as the area of land that one pump can irrigate in one day. Each week, the number of pump-days needed to irrigate all of the pump owners' land, A, is given by:

$$N\beta[7(1-\theta)+(7-\eta)\theta] \tag{1}$$

where the first term, $N\beta[7(1-\theta)]$, represents the pump-days per week that pumps that are never rented by their owners are in use. If no pumps are rented and all pumps are used fully, then $\theta = 0$, $\beta = 1$, and the term equals $7N$ i.e. all pumps are in use all the time on their owners' land. The second term in the parentheses, $N\beta[(7-\eta)\theta]$, represents the pump-days used on owners' land for those pumps that are occasionally rented by their owners.

It follows that the area that each individual irrigation pump can irrigate in a day is:

$$\frac{A}{N\beta[7(1-\theta)+(7-\eta)\theta]} = \frac{A}{N\beta(7-\theta\eta)} \tag{2}$$

As before, if all pumps are fully used and no pumps are rented, the expression simplifies to the intuitive $A/7N$.

The total pump-days of irrigation service provision is given by $N\theta\eta$, where η is a choice made by the pump owners. We assume that pumps that are rented or loaned are fully utilized during the loan/rental period. The increase in irrigated area as a result of irrigation as a service provision is then:

$$\frac{AN\theta\eta}{N\beta(7-\theta\eta)} = \frac{A\theta\eta}{\beta(7-\theta\eta)} \tag{3}$$

If A is unknown, this corresponds to a proportional increase in irrigated area of

$$\frac{\theta\eta}{\beta(7-\theta\eta)} \tag{4}$$

Note that neither of the unknown parameters, N (number of pumps) and A (pump owners' irrigated land area), appear in the final estimate. Table 1 below shows the estimated increases in irrigated area resulting from irrigation as a service provision for Bugesera and Nyagatare Districts, based on fieldwork. Values of θ and η are based on field observations. As can be seen, the estimates are sensitive to all parameters. However, for a range of reasonable parameters, it is likely that irrigation as a service has resulted in a significant increase in irrigated area in both districts.

Several results can be pointed out. As expected, the irrigated area served increases as the proportion of owners and the average days per week that pumps are rented increase. The irrigated area served also increases as pump utilization rate *decreases*. While this result may seem counterintuitive, it follows directly from the assumptions made. The area irrigated by pump owners using their own pumps is unknown but fixed. As asset utilization rate decreases, this implies that the same (unknown) area can be irrigated in less time. Each pump is able to irrigate more area per unit time, including time it is rented out. As a result, all else equal, area reached through irrigation as a service increases as asset utilization rate decreases.

Table 1: Estimated increases in irrigated area reached through irrigation as a service

	Bugusera District		**Nyagatare District**	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Proportion of owners who rent, θ	0.5	0.6	0.2	0.4
Average days per week pumps are rentable, η	1	3	1	3
Proportional increase in irrigated area, $\beta = 1$ (full asset utilization)	0.077	0.35	0.029	0.21
Proportional increase in irrigated area, $\beta = 0.5$	0.15	0.69	0.059	0.41
Proportional increase in irrigated area, $\beta = 0.25$	0.31	1.38	0.12	0.83