Official Journal of the World Water Council
Water Policy



Water Policy Vol 24 No 6, 1061 doi: 10.2166/wp.2022.043

# Increasing production efficiency of irrigation systems through stakeholder participation

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## ABSTRACT

Irrigation projects have elicited ambiguous views, if not outright animosity, during the past four decades. Aside from environmental and relocation concerns, low productivity is a source of criticism. Irrigation management systems in developing countries seem to have historically underperformed due to government control. Weak institutional arrangements have hindered effective and timely water distribution. There is widespread dissatisfaction with technocratic top-down programmes imposed with little community support. A rising recognition that more advanced engineering and information technologies are not the primary drivers of increased irrigation potential utilisation has resulted in an emphasis on farmer-led irrigation. Many developing countries have introduced reform instruments since the 1980s, with the most notable paradigm being a move from government control to participative management by stakeholders. This study looks into the situation in Cambodia where participation of farmers in managing irrigation schemes is being sought through the formation of Farmers Water Users Committees. The study quantifies the improvement in project performance with farmers' participation through Farmers Water Users Committees and finds it significant. Furthermore, using difference-in-difference methodology, this research finds that the improvement is not a blip and is sustained over the medium term.

**Key words:** irrigation, natural experiment, participation, production efficiency, water management, water resources

## HIGHLIGHTS

- The study has evaluated and, for the first time, quantified the impact of stakeholder participation in the effectiveness of irrigation projects in Cambodia.
- This is the first longitudinal study using panel data and finds that participation improves project effectiveness over the medium term.

## 1. INTRODUCTION

While the economic productivity of a number of human activities depends on access to freshwater resources, agriculture is a major player in the human appropriation of water resources. Irrigation has been essential for the successful growing of crops right across the world for thousands of years. Human settlements grew where natural irrigation was available. The earliest known settlement to be classified as permanent was Jericho, around ten millennia back. The habitation had natural irrigation from the Jordan River, allowing it to grow the opobalsamum shrub and produce and export the most expensive essential oil in the ancient world (Department for Levelling

Up, Housing and Communities, 2022). Residents of Jericho enjoyed architecture that included a holy shrine and painted skulls that were the world's first attempt at portraiture at the dawn of time.

Human controlled irrigation – the agricultural process of applying controlled amounts of water to land to assist in the production of crops – came a few millennia later and was developed independently by many cultures across the world. Around 3500 BC, irrigation from the Euphrates river facilitated the development of the Sumerian settlement of Uruk. Irrigation supported a vast variety of vegetation and the domestication of grain led to the swelling of Uruk's harvest leading to trade, advancements in writing, and specialised crafts including the potter's wheel (Algaze, 1993). While the irrigation techniques have continued to develop, the basic process of artificially directing water towards agricultural land has remained a mainstay of farming for thousands of years, allowing humans to dominate their environment wherever they lived and it remains so to this day. About 70% of global freshwater withdrawals are used for irrigation to increase crop production. While irrigated areas account for 18% of global croplands, they contribute to about 40% of the global production of food and fibre. Most common irrigation systems are surface systems that involve water being moved across the surface of a farming area to wet the soil.

Irrigation demonstrates the ability of humans to improve their lives through the use of innovative techniques. In newly independent countries, irrigation projects symbolised technological prowess, food security, and economic development. The projects were seen as a defence against famine that ravaged some of these countries in the colonial times. During a ceremony commemorating the Bhakra Nangal dam project in 1954, India's first Prime Minister Jawaharlal Nehru famously called irrigation dams the temples of modern India. Such sentiments were echoed across post-colonial Asia until the 1970s.

For the last four decades, irrigation projects have been evoking ambivalent feelings, even hostility. Apart from environmental and displacement aspects, the criticism relates to low productivity. There is widespread disenchantment with the technocratic top-down programmes imposed with minimal community support and a growing realisation that more sophisticated engineering and information technology are not the main drivers of higher utilisation of irrigation potential. There has been an increase in focus within the World Bank and other agencies on farmer-led irrigation. Over time the managers have come to accept the involvement of stakeholders in decision making. Whether participation by users' groups improves efficiency and whether this improvement is sustainable in the medium term is not yet clear. This research examines this issue in Cambodia where the government and international agencies are trying hard to introduce and encourage farmers' participation in managing irrigation schemes.

## 2. PARTICIPATION IN IRRIGATION

Irrigation water is a common good with special characteristics. It features attributes of public and private goods and of common property resources, depending on the situation. Irrigation can be viewed as an insurance. It enables farmers to produce good, reliable crop yields, often two to three times those of rain-fed crops. Irrigation can reduce the impacts of frequent and even severe droughts though it does not eliminate all the risks of water shortages. Irrigation systems have an inbuilt technical externality due to an asymmetry: the activities of the farmers of the head reaches affect the farmers of the tail reaches but not vice versa. All farmers desire an assured supply of water at the time of their choice. The factors that need to be considered are assurance, reciprocity, and fairness.

In view of the need for both the regulatory, as well as enabling functions, it was assumed that only an active state apparatus can provide efficiency and equity. For ideological and practical reasons, irrigation projects are mostly in the public sector. They are difficult to fund on a commercial basis because they cannot deliver short-term predictable financial returns. Irrigation projects are self-contained investments that are dependent on local off-take, or the sustainability of the agricultural activities that use the water. Because water is one of the inputs into the production process, along with water resource management, credit, fertiliser, and market access, the ability and willingness to pay for water services must be weighed against total farmer capacities. There is no guarantee that investments will be recovered.

Most developing countries, especially those that emerged from conflict situations, do not have a coherent bureaucracy. In many such countries, the state is viewed by the agrarian society as a predatory organisation. Even in the presence of a democratic system with a well-established bureaucracy, the performance of government-run irrigation projects has been poor. Robert Wade's (1982) analysis of irrigation in India revealed that an important reason for poor performance is the collection of the vast amount of illicit revenue by irrigation engineers in the field from the distribution of water and contracts, part of which is passed on to superior officers and politicians.

The recognition that a collaborative decision-making process must take into account a wide range of values, knowledge, and viewpoints has resulted in a slew of new approaches and processes being proposed to aid irrigation management, which includes participatory forms of management (Von Korff *et al.*, 2012). Empirical cross-disciplinary research in collaboration with practitioners in close cooperation with policy makers and other interested parties such as farmers can give useful results (Raya & Gupta, 2022).

Since the 1980s, there has been growing recognition that farmers are highly entrepreneurial and small-scale farmers have for many centuries been developing a wide range of irrigation systems independent of development agencies or governments. Ostrom (1995) describes a World Bank financed irrigation scheme in Nepal for which the loan documents mentioned that the project is important because there was no irrigation in that valley. However, when the project was delayed, additional surveying revealed that there were in fact 32 existing and fully operational irrigation schemes in existence. Since these schemes were being managed by farmers and not controlled by the government, they were invisible to the modernist engineers. Detailed studies of the operation and productivity of the irrigation schemes with modern head-works found that they were actually less productive in delivering water to system tail-enders than were farmer-managed irrigation schemes without modern infrastructure. Related work by Uphoff (1992) on irrigation schemes in Sri Lanka reached a similar conclusion. In the current study, the researchers saw a farmer-managed irrigation scheme in Cambodia where a person had to climb a tree to reach a platform from where the gate is opened or closed; yet the irrigation scheme was working well.

During the last half century, there has been a divergence in the trajectory of agricultural development in Sub-Saharan Africa and Asia. In the former, the focus has largely been on expanding the irrigated area, whereas, in the latter, the emphasis has been on intensifying production on existing land by rehabilitating and modernising existing irrigation infrastructure (Makin, 2016, p. 2). In the eyes of the western aid agencies, the supposed trade-off in the modernisation of irrigation schemes in Asia was between the technical benefits of the modern infrastructure versus the erosion (or shift) in social capital needed to underpin the modern infrastructure; but when informal was not replaced with effective formal administration the new schemes could be 'lose–lose': i.e. 'worse at social capital and worse at irrigation' (Andrews *et al.*, 2017, p. 46).

## 3. THE SETTING

The research area encompasses the Kingdom of Cambodia. While the United Nations designates Cambodia as a least developed country, agriculture remains the dominant economic sector which makes irrigation important. The Khmer (Cambodians) account for the vast majority of the population producing a homogeneity unique in Southeast Asia that has encouraged a strong sense of national identity. Buddhism is enshrined in the constitution as the official state religion and is practised by more than 97% of the population. Perhaps due to a long history of instability, conflict and genocide, liberal democracy has not taken root in the country as yet. History, culture, geography, and politics have all contributed to Cambodia's nightmare, albeit in different ways. The latest Rule of Law Index compiled by the World Justice Project ranks Cambodia 138th out of 139 countries. In Transparency International's (2022) Corruption Perception Index 2021, Cambodia comes 125th out of 180 countries surveyed. Cambodians are oddly reluctant to analyse or confront the violence and corruption that plagues their society. To do so would require a degree of self-examination for which they are unprepared and which, instinctively, they prefer to avoid (Hinton, 2022). The absence of a robust government structure, dependable and competent public institutions and a coherent state bureaucracy makes state-society synergy hard to achieve.

Before the first civilisation had developed, the people who entered Southeast Asia followed freshwater from the north to the south. According to a prevalent myth, the first royal lineage of Cambodia was formed when a son was born to a water princess. The Khmer Empire between the 9th and 15th century was known as a 'hydraulic economy' because of its advanced irrigation system and the numerous canals leading into the waterways of the Mekong delta contributing to economic growth. Rice production as a result of the enormous irrigation systems fed a large population. Irrigation management and water distribution were the responsibility of the king and his staff, who oversaw a complicated network of hydraulic infrastructure including canals, moats, and large reservoirs. Rice farmers and fishermen formed a large majority of the population. The rivers have been inextricably linked to the religious practices and culture of Cambodia (Chandler, 1992). The medieval kings had apparently worked out the day on which the Mekong and the Bassac rivers would, once a year, suddenly start to flood, conjoin, and under tremendous water pressure, appear actually to reverse their flow back into the Tonle Sap lake. There was a ceremony at which the 'divinely appointed' King would order the water to flow backwards. Right up to the 21st century, the showman King Norodom Sihanouk exploited this phenomenon with great aplomb.

With the fall of the Khmer empire in the 15th century, the vast and intricate canal system silted up owing to disuse and lack of repair. While political stability was restored when Cambodia became a French protectorate in 1863, infrastructure and public works during the French rule were limited to roads and railways and not irrigation. After a violent struggle, France formally agreed to recognise Cambodia's independence in December 1954. Little infrastructure was created during the period immediately following independence as the country was racked with political instability and insurgency.

In 1975, after four centuries of neglect, irrigation infrastructure was given priority, in fact too high a priority, when the genocidal Khmer Rouge came to power. Between 1975 and 1979, the provision of irrigation was taken to extremes and the whole population was effectively reduced to slave labour in a programme of public works that sought to subdivide the country into squares of 100 m, with an irrigation canal every 1 km. Deriving their authority from the old legends, they adopted an all enslaving idea of 'Angka' to re-establish the glory of the hydraulic economy of the ancient Angkor empire. The Khmer Rouge's policy of depopulating the cities led to the elimination of a large number of intellectuals, including engineers. Most of the newly built systems were ill-designed due to a lack of knowledge of hydrology among the Khmer Rouge cadres. Canals were laid in simple parallel lines regardless of terrain, often accelerating drainage from high areas and flooding low areas. The fall of the Khmer Rouge regime led to chaos and uncertainty with people returning to their original places of residence and irrigation projects remained without maintenance though the new government provided some support to 'solidarity groups' of farmers from 1980 onwards. In 1985, the projects were transferred to the users, but with limited resources, there was little or no maintenance. In 1990, international aid agencies entered the field and a few pilot projects were started. With the help of the multilateral and bilateral aid agencies, many of the deteriorating projects were rehabilitated. Since 1994, the government has started the programme of transferring operations and maintenance to Farmers Water User Committees (FWUCs) and since the mid-2000s, several development agencies have carried out projects to 'rehabilitate' the canals and promote participation by users (Venot *et al.*, 2022).

The legal and political framework for water resources management in Cambodia can be described as 'fragmented' at best. Despite attempts to centralise water governance under the Ministry of Water Resources and Meteorology (MOWRAM), inter-agency coordination has been limited by rivalry and weak lines of communication (Mang, 2009). In 2007, a new water law was promulgated which sought to improve Cambodia's water resources management and governance. As part of this law, FWUCs have a legal mandate to manage local irrigation systems. Due to a lack of human and financial resources, MOWRAM has not been able to sustain its support to FWUC further than the short-term process of their creation. In many situations, further assistance is offered through programmes sponsored by external donors and is only available for the period of the project. However, FWUCs have limited capacities and tools to ensure sustainable management of their schemes after the external support ends.

FWUCs are obliged to ensure equal and sustainable distribution of irrigation water for farmers. The services that the FWUCs provide are (1) distribution of water; (2) maintenance of the irrigation system; (3) dissemination of information; and (4) Conflict resolution. This requires farmers' involvement in (1) regular payment of irrigation service fee; (2) attendance at meetings; (3) involvement in renovation and maintenance activities; and (4) serving as administrators or decision-makers. The combined effects of the FWUC being a Foreign-introduced Exogenous Institution and the loose structure of Southeast Asian rural societies affect farmers' mindset resulting in low-level participation of farmers.

FWUC is not yet a self-supporting or independent organisation. It requires support from the government and international NGOs, especially in building the capacities of the FWUC officials in operating and managing the irrigation system as also for accounting. The irrigation service fee is charged per acre. The land titles are issued by the government and FWUCs have a tough time in dealing with provincial level officials. This results in many farmers paying incorrect charges. The governments at the national and provincial levels view farmers' participation through FWUCs as an instrument of the higher level of utilisation of irrigation potential. However, due to asymmetry of power, unless supported by international NGOs, the institutional arrangement collapses.

There have been few studies on water resources and water harvesting in Cambodia (Ministry of Environment, 2013). Two case studies by Perera (2006), one by Sam & Shinogi (2015), and three by Sithirith (2017) find that FWUCs are able to function effectively only when supported by the government or the donors. Improving the functionality of water resource infrastructure required involving local communities and connecting irrigation improvements with local capacity. This happens only when handholding is available from outside.

In a research project, it was tested whether participation by beneficiaries, as evidenced through a functioning FWUC, can bring about any improvement. This was done on the basis of cross-section data for the year 2007. As a first step, the mean and median of project effectiveness (the proportion of the designed command area actually being irrigated) of the projects with participation were compared with those without participation. Project efficacy was found to be higher in projects involving participation. The statistical significance of the differences in means in project effectiveness ratios was based upon the $t$ statistic from a parametric test (on the assumption of unequal variances) of whether the difference is significantly different from zero. The Wilcoxon Rank-Sum test was performed to look for differences in medians. The difference in means and medians was found to be highly significant. The regression results also found the participation variable highly significant. The comparative analysis yielded a strong association between project performance and beneficiary participation. The results were published in this journal (Asthana, 2010) and provided development practitioners with strong statistical findings that participation causes higher project effectiveness. Now that considerable time has passed we are trying to see whether the effect is effervescent (back to normal, after a while), the improvement is persistent or improves with time.

## 4. METHODS

We use the difference-in-difference method that goes back to the work of Snow (1855) in the water sector. To prove that cholera is caused by bad water rather than bad air (the dominant theory at the time), Snow compared the changes in cholera mortality rates in the districts served by two water utilities that in 1849 obtained their water supply from the river Thames in central London. In 1852, one of the utilities moved its water works upriver to an area relatively free of sewage. Cholera mortality fell in both cases but more so in the districts supplied by the company whose water works moved upriver. Natural experiments and the difference-in-difference (also called D-in-D or DD method) did not attract much attention in the social sciences literature for several decades. Since the 1990s, DD methods have moved into mainstream social science research. The methodology has been more or less standardised and is being used frequently in the water sector (Asthana, 2013). Empirical econometricians Guido Imbens, David Card, and Joshua Angrist who have shown what conclusions about cause and effect can be drawn from natural experiments were awarded the Nobel Prize for Economics in 2021.

### 4.1. Sample

This study is based on analyses of medium and minor irrigation projects, which were selected on a random basis for a study by the Japanese Bank of International Cooperation through consultants M/s Mott MacDonald for another broader research project. Of the 50 projects in the study area, 21 projects had functioning FWUCs in the year 2007 (Asthana, 2010). Another 50 irrigation schemes were added to the research project and FWUCs were operating in all the projects by 2020. Our sample covers 79 projects where FWUCs were established between 2008 and 2020. The study required contacting the officials of MOWRAM as also international support agencies and their consultants. Since the focus of the study was on the physical implementation of the projects, the data were verified and updated for each project up to 2021 on the basis of field visits. The number of projects in which the FWUCs were functioning is given in Figure 1.

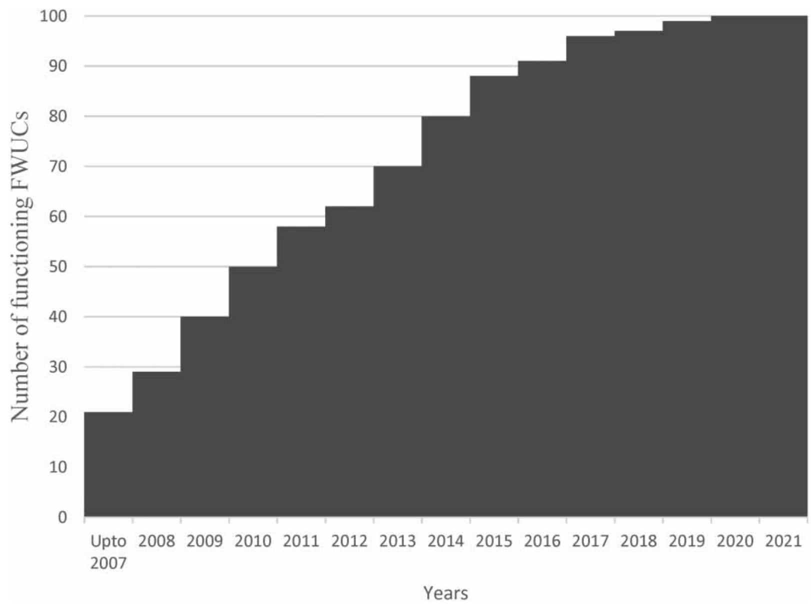


**Fig. 1** | Year wise growth of Farmers Water Users Committees.

### 4.2. Variables

As a determinant of project efficiency, independent variable participation is a dummy variable, taking a value of 1 for where FWUC was an established project and of 0 otherwise. In the choice of independent variables, we have followed Asthana (2010) wherein the independent variables have been chosen on the basis of economic logic rather than through computer programs which facilitate choosing of variables that give the highest adjusted $R^2$.

One obvious variable that can affect project effectiveness is the size of the project. When we regress the project effectiveness ratio against the size of the project (designed command area), we find a significant negative relationship ($t > 2.0$). Similar results are obtained when the project effectiveness ratio is regressed against the natural logarithm of the size of the project. We use the MWD test, and find that the log of size will be more appropriate as an explanatory variable. On the basis of a similar analysis, the log of age and, as a variable for remoteness, the log of distance were included as the explanatory variables. Other variables included are the age of project, rainfall, literacy level, and per capita income.

### 4.3. Endogeneity and halo effect

Is it possible that just as participation influences effectiveness, effectiveness influences participation? When the project is effective for extraneous reasons, do farmers join the FWUC? It is important to test for endogeneity because having endogenous regressors in a model will cause ordinary least squares (OLS) estimators to fail, as one of OLS's assumptions is that the predictor variable and the error term have no correlation. We apply the Hausman specification test to detect endogenous regressors (predictor variables) and do not find any endogeneity. In the absence of endogeneity, OLS estimates are unbiased (even for small samples) and have minimum variance. In such a case, OLS estimators will be BLUE (best linear unbiased estimators). Participation is generally regarded as a good thing. However, because the project effectiveness is a cardinal variable and not a subjectively measured ordinal variable, we do not expect any systematic measurement error caused by the halo effect.

### 4.4. Identification strategy

This paper uses the cross-irrigation project and cross-time variation in the participation to determine its effect. The data cover all years from 2009 to 2020. It was felt that a period of 13 years is long enough to make a meaningful assessment of the trend. Moreover, this panel data allows us to exploit only the variation in time of introduction of participation, holding the decision to introduce participation fixed for all irrigation projects in the sample. The identification strategy is valid as long as the changes in the outcome variable, that is, project effectiveness, would be similar across irrigation projects in the absence of FWUCs. The required assumption for the estimations to be valid is that the changes in the outcome variable would not have differed systematically between the treatment irrigation projects and the control irrigation projects if participation had not occurred. While this assumption is essentially untestable, it is likely to hold if there are no initial systematic differences. We employed three methods for checking for any endogeneity. First, we interviewed the organisers who stated that the programme of participation had nothing to do with the changes in effectiveness of a particular irrigation project in the past or the expectation thereof in the future. To check whether the irrigation projects are indeed comparable from this point of view, we split our data into two parts – projects with early participation, that is, the irrigation projects in which FWUC started operating earlier and the irrigation projects where FWUC came into operation later. The comparison shows that the difference between the two groups is statistically insignificant. To further examine the pattern of timing of participation, we regressed each of the variables on the year of participation. The coefficients on the year of implementation were not found to be significant at even a 10% level (Table 1).

**Table 1** | Project characteristics.

| (1) | Early participation average (2) | Late participation average (3) | Difference in averages (4) | Coefficient on year of participation (5) |
|---|---|---|---|---|
| Changes in outcome variable between 2016 and 2021 | | | | |
| Project effectiveness ratio | 0.121 | 0.117 | 0.004 | 0.001 |
| Background variable as in 2021 | | | | |
| Total command area (in ha) | 1,101 | 1,079 | 22 | 21 |
| Age of project (years since construction/rehabilitation) | 19.1 | 17.9 | 1.2 | 0.18 |
| Remoteness (distance from capital in km) | 189 | 207 | −18 | 3.3 |
| Rainfall (in cm per year) | 167.5 | 168.5 | −1.0 | 3.2 |
| Literacy (in % for 15+ age group in project area) | 83.2 | 82.6 | 0.4 | 1.7 |
| Per capita income (in US$ in the project area) | 1,293 | 1,269 | 24 | 25 |
| *N* | 39 | 39 | | |

*Note*: None of the differences in column 4 and none of the coefficients in column 5 are significant even at the 10% significance level.

We can safely conclude that there is no statistically significant trend for changes in any of these variables. The fact that the irrigation projects were not randomly selected for implementation of participation does not invalidate the identification strategy as the timing of participation in various projects was not related to the lagged values or expected future values of outcome variables of interest. The identification strategy relies on the changes over time being similar across irrigation projects; the checks described above validate the strategy.

## 5. RESULTS AND DISCUSSION

According to the identification strategy described previously, we obtain the main results by running the following regression with OLS:

$$y_{it} = \alpha + \beta_i + \gamma_t + \pi P_{it} + \varepsilon_{it} \quad (1)$$

where the subscript $i$ denotes the project and $t$ denotes years. This regression includes project fixed effects $\beta_i$ and annual fixed effects $\gamma_t$. The variable $P_{it}$ is the participation dummy and, for each project, it is equal to one for the year in which the FWUC became operational and for all following years. We run the regression without and with the background variables. The standard errors of the regressions are clustered at the project level. As explained in Bertrand *et al.* (2004), clustering at this level helps to prevent the problem of serial correlation in difference-in-difference estimates which use a large number of time periods. Table 2 shows the main results of this paper.

We find the participation variable highly significant. As for background variables, from the last column of Table 2, we see that the project effectiveness of smaller, newer projects is higher and that of projects located in remote areas is lower. While literacy has a positive effect on the project effectiveness, the coefficients of rainfall and per capita income in the area are not significant.

While the regression above estimates only the average effect of functioning of FWUC, it is also important to check how this effect looks over time. Since the implementations of participation were phased in over time and since all the projects covered in the regression were those where FWUC was established by 2010, the outcome data for all lags and leads for all projects was not observed. For example, we do not have $Y_{+1}$ data for

**Table 2** | Regression results.

| | Regression coefficients | |
|---|---|---|
| **Explanatory variables** | **Bivariate** | **Multivariate** |
| Participation variable | 0.168** | 0.119** |
| Total command area (log of) | | −0.0009* |
| Rainfall (in 100 cm per year) | | 0.010 |
| Age of project (log of) | | −0.0002** |
| Distance from capital (log of) | | −0.0002* |
| Literacy (in %) | | −0.0003** |
| Per capita income (in US$) | | 0.0009 |
| Adjusted $R^2$ | 0.53 | 0.68 |
| Sample size | 79 | 79 |

*Significant at the 5% level.
**Significant at the 1% level.

the year 2021 as no FWUC was established in 2020, and $Y_{+2}$ for the years 2020 and 2021. Data availability is shown in Figure 2.

To check how this effect looks over time, we run the following regression with OLS:

$$y_{it} = \alpha + \beta_i + \gamma_t + \Sigma \delta_l Y_{li} + \varepsilon_{it} \tag{2}$$

where $Y_l$ is a set of dummy variables for lag and lead years relative to the time of implementation in a given project. For example, $Y_{-1}$ is equal to one for the last year before the FWUC became operational, whereas $Y_{+1}$ is equal to one for the year after the year in which the FWUC started working. Keeping in view the limitations of data

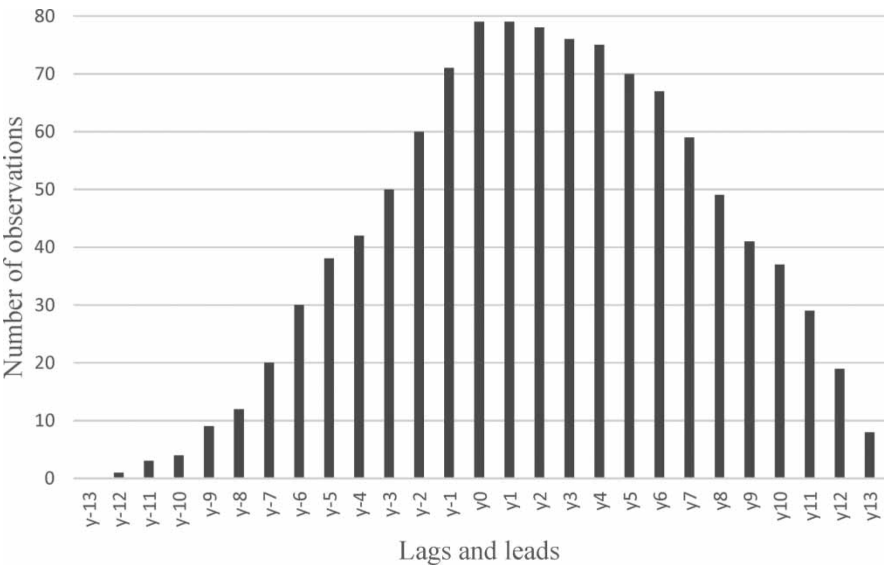


**Fig. 2** | Data availability.

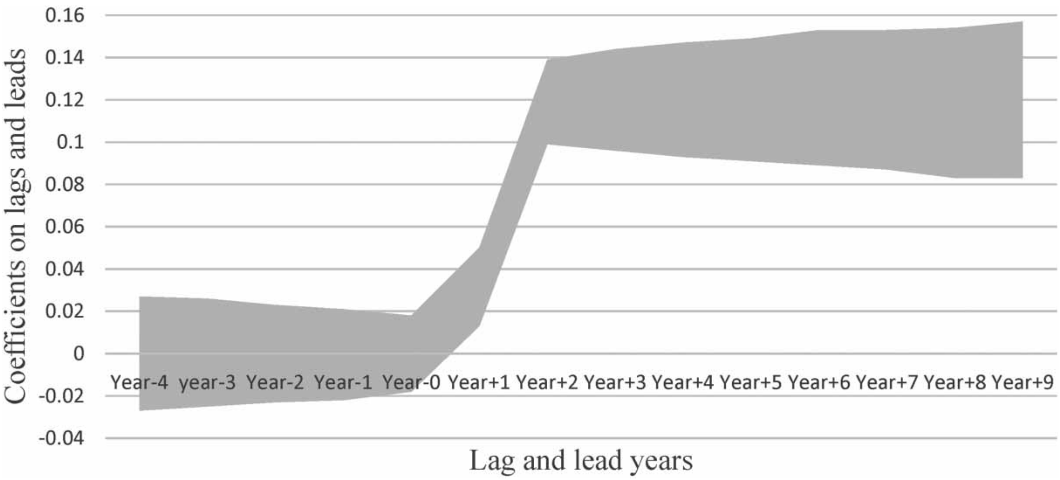


**Fig. 3** | Effect of participation on project performance over time.

availability, we limit this regression to observations that fall between $Y_{-5}$ to $Y_{+9}$. $Y_{-5}$ is also the 'omitted' as all other observations are being compared with these observations. We do not expect smooth plots of confidence because the sample size in each year is different, causing 'missing data' problems. Figure 3 shows the plot of the coefficient of participation over time.

The grey area in this figure is the 95% confidence band of the estimates. We observe that from $Y_0$ onwards, the whole band remains consistently above the $x$-axis in Figure 3. Our analysis indicates that the benefits of participation are not ephemeral, they last over the medium term.

## 6. CONCLUSION

In developing countries, investments in irrigated agriculture have been plagued by a history of cost-overruns, poorly performing systems, and concerns regarding sustainability, governance, and equity of investments in the sector. In spite of past failures, irrigation still has significant potential for economic growth, food security, and poverty reduction. Against this backdrop, the need to tap the potential of irrigation in all its forms has never been greater. Participatory management is based on the idea of empowering group members to participate in functional decision making. It also prioritises community specific actions' success or failure in conservation by accepting local people's inputs and participation (Ward *et al.*, 2021). In most developing countries, irrigation management systems have not performed well in the past because their management was entirely and poorly controlled by governments (Abernethy, 2010). Weak institutional arrangements have impacted efficient and timely water delivery and farmer productivity in turn. Since the 1980s, instruments of reform have been implemented in many developing countries. The most significant paradigm of these reforms is a shift from construction and rehabilitation to operations and maintenance, which can improve water distribution A belief has emerged that farmer participation would contribute to increased performance. This belief came in part from the framing of neoliberal development discourse about the problems of the state and the promise of private action and in part from initial successful experiences in farmer-managed irrigation systems. This research indicates that improvement of project performance with participation is sustained over time.

## ACKNOWLEDGEMENTS

The author thankfully acknowledges comments from S. J. Chión Chacón, C. Vincent, the PUCP Value Chain Innovation Center, and three anonymous referees on the earlier version of the manuscript. Valuable logistical support from Mott Macdonald and excellent research assistance from Omayoga Ltd.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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First received 15 February 2022; accepted in revised form 15 April 2022. Available online 22 April 2022