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What role can small-scale irrigation play in promoting inclusive rural transformation? Evidence from smallholder rice farmers in the Philippines

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ABSTRACT

We investigate how user-managed small-scale irrigation can influence inclusive rural transformation. Cultivating inclusive rural transformation is key to sustainable growth and poverty reduction in developing countries, but existing research rarely analyses the holistic impacts of rural development projects on this process. We use a combination of quantitative and qualitative data to rigorously measure impacts and uncover the causal pathways of a canal irrigation project for rice farmers in the Philippines, finding that positive impacts were heavily determined by market access and the strength of the local economy. We also find limited impacts for poorer farmers located further downstream on the irrigation canals. Based on these findings, we draw several lessons about the complementary conditions and support that are required in order for irrigation to be an effective tool in promoting inclusive rural transformation in developing countries.

1. Introduction

It is well-documented that improved irrigation increases agricultural productivity, but higher crop yields alone are not enough to drive transformational change for rural households (Lipton et al., 2003; Pinstrup-Andersen and Shimokawa, 2006). Rural transformation refers to the transition of a low productivity, labour-intensive rural economy to one that is market-oriented, capital-intensive, and comprised of productive on- and off-farm activities (Timmer, 2009; Berdegué et al., 2013). Rising crop productivity is part of this transition, but sustainable and inclusive rural transformation also involves changes in the composition of livelihood activities and continuous improvements in incomes, assets, off-farm productivity, social capital, nutrition, education and gender equity (IFAD, 2016; FAO, 2017). By increasing and stabilising yields, along with other mechanisms, better irrigation has the potential to contribute to each of these aspects of inclusive rural transformation, but empirical evidence on its wider impacts is scarce.

This paper addresses this research gap with an in-depth impact evaluation of a small-scale irrigation project for smallholder rice farmers in the Philippines, in a bid to inform ongoing efforts to shape and accelerate the most desirable forms of rural transformation in developing countries. We focus on smallholder farmers as they constitute some of the world's poorest people and are particularly at risk of exclusion from the rural transformation process (FAO, 2017), and focus on small-scale irrigation in particular because the low cost of its construction and maintenance means it is well suited to supporting this group (Xie et al., 2014). Focusing on user-managed irrigation systems also helps to fill a significant knowledge gap on the benefits of Irrigation Management Transfer, about which there remains considerable doubts (Senanayake et al., 2015).

We use a combination of quantitative and qualitative data from treatment and control households to analyse the project’s impacts on a set of indicators within a novel inclusive rural transformation framework. As part of the investigation, we take advantage of the differences between the project regions to identify important contextual factors that shaped impacts. To our knowledge, this is the first impact evaluation study to apply an inclusive rural transformation framework in this manner.

The remainder of the paper first outlines the potential linkages between small-scale irrigation and inclusive rural transformation around which the framework of impact indicators is based. This is followed by an overview of the case study project; details of the data and methodology; a profile of the sample; a presentation and discussion of the results; and the conclusions and policy implications.

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Potential links between small-scale irrigation and inclusive rural transformation

There is a large body of evidence showing that well-managed irrigation systems help farmers to increase their cropping intensity and cultivate year-round, leading to higher and more stable crop yields (Lipton et al., 2003; Hussain and Hanjra, 2004; Pinstrup-Andersen and Shimokawa, 2006). This effect on agricultural production can contribute in-turn to the rural transformation processes in several ways. As evidenced during the Green Revolution, for instance, more reliable production can promote agricultural modernisation by increasing farmers' incentives to adopt new technologies (Evenson and Gollin, 2003; Estudillo and Keijiro, 2006; Hazell, 2009). Improved irrigation could also promote higher-value, market-oriented agricultural production by increasing farmers' production capacity and marketable surplus, and potentially by allowing farmers to grow cash crops that are hard to grow with rain-fed irrigation (Namara et al., 2010; Burney and Naylor, 2012). In Bangladesh, for instance, Mottaleb et al. (2015) find that better irrigation infrastructure increased rice farmers' market integration thanks to their increased marketable surplus, while in India Mishra et al. (2018) find a positive link between irrigation and contract farming among smallholders.

In addition, more reliable and efficient crop production could also change risk attitudes and reduce labour requirements, both of which may encourage farmers to advance into the type of productive off-farm activities characteristic of a transforming economy (Freguin-Gresh et al., 2012). As irrigation water can also be used to improve grazing lands and for other livestock needs, better irrigation can especially encourage more livestock production, a link supported by evidence from Mali and Nepal (Dillon, 2011; ADB, 2012).

Although largely untested, better irrigation could also theoretically contribute to improved nutrition, education and social capital, all key components of a sustainable rural transformation process. Better nutrition and food security may be achieved as households consume more fruits, vegetables, staples and livestock products thanks to their higher crop yields, enhanced livestock production and greater market integration. Higher labour productivity and income as a result of better irrigation could also reduce the need for children to work on family farms, leading to higher school enrolment and attendance (FAO, 2012). An irrigation project in Madagascar, for instance, was found to have increased incomes, and as a result, increased the amount that farmers spent on their children's education (Ring et al., 2018). Higher education also has the potential to in-turn complement the impact of irrigation on productivity as part of a virtuous cycle (Hanjra et al., 2009). Social capital could be improved through user-managed irrigation schemes, a common aspect of small-scale irrigation which can increase social cohesion and mutual support (Kähkönen, 1999). An irrigation project in Mali, for instance, found evidence of increased meal sharing as a form of risk protection among households with irrigation (Dillon, 2011). As with education, higher social capital can also feed back into the performance of the irrigation system by increasing collective action within user-managed systems, as has been found among water user associations in Japan (Takayama et al., 2018).

The capacity of better irrigation to promote transformation that is inclusive lies in its potential benefits for smallholder farmers, as well as women, two of the groups most at risk of exclusion (FAO, 2017). Regarding smallholders, small-scale irrigation systems are cheaper to implement and maintain, making them an accessible and sustainable option for these farmers. Among smallholders, those located downstream—who are usually the poorest and often suffer from overuse of water by those located upstream—stand to benefit the most from more efficient and better-managed canal systems (Namara et al., 2010; Darko et al., 2016). Moreover, research shows that where there are low transmission losses and other supporting factors, equitable irrigation systems are also the most productive for all users (Steiner and Walter, 1992).

Women could benefit through new economic opportunities as livelihoods are enhanced through the mechanisms discussed above. However, there is also potential for women to be left to tend the family farm while men pursue other high-value activities (Smith, 2004; Slavchevska et al., 2016). When they engage in democratically managed water user groups, women could also improve their representation and responsibilities within their communities (Sargeson and Jacka, 2017). In practice, however, these groups tend to suffer from high levels of exclusion, especially of women (Meinzen-Dick and Zwarteveen, 1998; Hussain, 2007).

Of the few existing studies that analyse the impact of irrigation on outcomes other than yields, the findings are not all positive, and some even demonstrate how irrigation can hinder the rural transformation process by making livelihoods more static. Studies of small-scale irrigation projects for rice farmers in the Philippines and India that compared treatment and control groups to measure impacts found that improved irrigation led beneficiaries to consolidate their livelihoods around rice production, while control households diversified and were able to keep pace with the income improvements of beneficiaries (World Bank, 2008; JICA, 2012). Without sufficient gains from specialisation, such an effect can hinder income growth and increase vulnerability to crop-specific shocks, thus reducing resilience and potentially hindering livelihood choices and technology adoption (Feder et al., 1985; Lin, 2011; Makate et al., 2016). There is also evidence that a lack of crop diversity can have a negative effect on dietary diversity and nutrition (Sekabira and Nalunga, 2015).

For the same projects in the Philippines and India, and another in Madagascar, impacts on inclusivity were also doubtful (World Bank, 2008; JICA, 2012; Ring et al., 2018). In each case, a failure of collective action and instances of elite capture within the user groups led to inequitable water distribution and hence increased inequality between up and downstream households. This confirms a common concern about small-scale canal irrigation that, without effective institutions managing the systems, the benefits of irrigation are likely to be unequal and captured by wealthier farmers located upstream (Magistro et al., 2007; Meinzen-Dick, 2007; World Bank, 2008; Burney and Naylor, 2012). Irrigation governance is a contested issue, and despite knowledge gaps and doubts over their effectiveness that are fuelled by findings such as those above, there are growing calls for an increase Irrigation Management Transfer, particularly in Africa, and for water user groups to be provided with more support, responsibility and involvement in policy formation (Senanayake et al., 2015; Mutambara et al., 2016; IFAD, 2018).

Findings from the studies mentioned above indicate that contextual factors such as the strength of local institutions will be important in determining which of the potential positive and negative links between irrigation and rural transformation are realised. The quality of local markets for inputs, outputs and credit are also likely to play an important role. Shifts in livelihood activities and benefits from specialisation, for instance, cannot be supported through irrigation without market and value chain connectivity (Namara et al., 2010; Freguin-Gresh et al., 2012; FAO, 2017).

2. Details of the case study project

The Irrigated Rice Production Enhancement Project (IRPEP) was implemented in Region VI (Western Visayas), Region VIII (Eastern Visayas) and Region X (Northern Mindanao) of the Philippines between 2010–2015, with a budget of $25 million. By the time of its completion, the project had provided support to 109 Communal Irrigation Systems (CIS) and the Irrigators' Associations (IAs) that manage them, covering 9,347 ha of land. CIS are externally initiated small-scale canal diversion irrigation systems that cover areas no larger than 1,000 ha and account for around 35 per cent of the total irrigated land in the country (NIA, 2017). For each CIS there is an IA composed of farmers who use the system which is tasked with maintaining the system, monitoring and policing water usage, and collecting user fees. The project targeted smallholders because they represent one of the country's poorest groups, due mainly to their low productivity and vulnerability to frequent climatic shocks, issues exacerbated by the low irrigation coverage in the country (Bordey et al., 2016).

IRPEP targeted CIS that had inadequate or inefficient water supply but high potential for improvement, and whose users had low income and crop productivity. For each of these CIS, IRPEP extended the canals of the CIS to cover more land, repaired canals damaged by climatic shocks, and lined canals with concrete to prevent water seepage. In addition, IRPEP provided training to IA officers to manage the system sustainably and equitably, encouraged women's participation in IAs, and offered marketing facilitation services. By lining the canals to reduce transmission losses, and improving system management, a key aim of the project was to improve water supply to households located downstream on the canals.

The three project regions have different characteristics that could influence the project's impacts in each area. For instance, Region VI and VIII are more at risk of climatic shocks compared to Region X. In fact, Region VIII was very severely affected by Super Typhoon Haiyan during the project's implementation, which caused serious damage to infrastructure and strained local institutions to cope with the implications—ultimately leading to them being excluded from this study so as not to distort the findings. Region X is much wealthier and its economy is mainly focused on cash crop production compared to Region VI, which is more focused on rice and livestock production and has a larger services sector (PSA, 2016). Despite being poorer, Region VI has experienced much larger poverty reduction in recent years, while growth in Region X has been less pro-poor, an issue attributed partly to the poor connectivity of households in rural areas (NEDA, 2017a, b; de la Rosa, 2018).

3. Data and methodology

3.1. Data and indicators

The quantitative data comes from a household questionnaire administered 18 months after IRPEP's completion, between March and May 2017. The electronic questionnaire was administered in Tagalog by a local data collection team, after being piloted in two neutral areas in Region X. We use data from 580 households in Region VI from 20 treatment and 20 control CIS, and 566 households in Region X from 16 treatment and 17 control CIS, equally split between beneficiary and control households.[1]

Several measures were taken during both the sampling and data analysis stages to obtain comparable treatment and control groups to measure IRPEP's impact. In the sampling stage, we first used Propensity Score Matching (PSM) to identify similar treatment and control CIS from a longlist of all the CIS in the two regions, with the scores calculated to represent the likelihood of a CIS being selected for IRPEP (Khandker et al., 2010). These scores were created using pre-project data linked to the project's selection criteria, including the average yields of users, distance to the regional capital, and the percentage of the system that is operational. By removing CIS without at least one match in the opposite group, we used the scores to create a shortlist of potential treatment and control CIS, from which we selected the final set for the sample with expert input from project staff. As the project may have had a spillover effect on the local economy, treatment and control CIS were not selected from within the same barangay. The sample was not separated at a higher administrative level (such as at the municipality or provincial level) because it was not expected that these spillover effects for small-scale rice farmers, in this timeframe, would be powerful enough to effect the local economy outside of the barangay.

From the selected CIS, we randomly selected households from amongst the CIS users for the household survey. This was done using lists of CIS members provided by the IA, from which all members were assigned a number and then selected through a random number generator. If a household was not available, two more attempts were made to conduct the interview, after which they were replaced with a new randomly selected household. After the data was collected, we verified the sample and removed 29 treatment households who still did not have access to rehabilitated irrigation, and 195 control households who had already received similar irrigation support from the Philippines government.

Complementary qualitative data were collected through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs). This included a KII with the National Project Coordinator and one FGD with other project staff at the national level, along with a KII and three FGDs with regional staff in each of the three project regions. In addition, 12 FGDs were held with officers from 6 treatment and 6 control IAs of the selected CIS, and 12 KIIs were also held with the Presidents of the same 12 IAs.

In order to test the potential linkages between irrigation and inclusive rural transformation outlined above, we use the household dataset to create indicators relating to agricultural production, income, livelihood composition, asset ownership, nutrition, social capital, education, and women's inclusion. Regarding agricultural productivity, we focus on rice production given its importance for smallholder livelihoods and because too few households grew other crops to facilitate a meaningful analysis. To represent asset ownership, we create an index that incorporates ownership of a range of productive assets, calculated using principle component analysis (Filmer and Pritchett, 2001). We also create an index for livestock ownership based on Tropical Livestock Units (Jahnke, 1982). Household Dietary Diversity Scores are used to assess impact on nutrition, whereby a score is assigned based on the consumption of different food groups in the past 24 h (FAO, 2010).

To assess impacts by parcel location, we compare key indicators from each impact domain for households who used only downstream parcels during the study period against households who used at least one up or midstream parcel. This classification was chosen so as to focus on those households likely to be the poorest (as all of their parcels are downstream)—although only a small proportion of households had a mix of up, mid and downstream parcels.

3.2. Impact estimation methodology

We estimate the average treatment effect on the treated (ATET) for IRPEP using an inverse probability weighted regression adjustment (IPWRA) approach, an impact estimation method that improves the comparability of the treatment and control samples using both weighting and regression adjustment (see Wooldridge, 2010; Austin and Stuart, 2015).

In this model, all treatment households are assigned a weight of one, and control households are assigned a weight that represents the inverse of the probability of their being a control household. These probability weights are calculated in a similar way to the Propensity Scores created for the sample design, whereby the likelihood of being in the treatment or control group is modelled based on pre-project livelihood capacities and other factors likely to influence their participation.[2] Using the inverse of the probability means that we assign greater

[1] The sample size was determined based on obtaining a Minimum Detectable Effect Size of 10%, using the formula outlined in World Bank (2007).

[2] The variables used to the create the scores consisted of the age, education and gender of the household head, household size, asset ownership at the start of the project, climatic shocks in the past year, number of IA members in the household, amount of land owned and proportion of land owned up/mid/downstream on the irrigation canal.

weight to control households who better represent a common treatment household, rather than a common control household. We employ the IPWRA model as it allows for the use of additional control variables within a regression framework which are important to incorporate in the case of detailed agricultural data, and does not require the dropping of a large number of households as with some PSM algorithms.

Formally, these weights are calculated as follows:

$$IPW_{ATET} = \mathrm{T} + \frac{P(1-\mathrm{T})}{1-P} \quad (1)$$

where T = the treatment status (1 = treated, 0 = control), and P = the probability of receiving the treatment they received given the set of weighting variables.

The next step is to run a regression adjustment model with the weights applied to each household. Separate models are run for the treatment and control groups, and in each case an expected value for the impact indicator is estimated. The formal specification of the regression model is as follows:

$$Y_i = \beta_0 + \beta_1 T_i + \Sigma X_{ij}\beta_{2j} + e_i \quad (2)$$

where Y is the outcome for household *i* for the impact indicator, T_i is the treatment status for household *i*, X_{ij} represents an $I \times J$ matrix of control variables used in the model, β_1 is the coefficient of the treatment indicator and β_{2j} is a vector of coefficients to be estimated for each of the control variables, β_o is the constant, and e_i is the error term, which was calculated using a cluster robust estimator at the province level (Cameron and Miller, 2015). Control variables were chosen based on their likelihoods to have influenced the outcome variable, while not having been affected by the project, meaning that different sets of control variables were used depending on the outcome variable being analysed. [3]

The final estimated impact, the ATET, is then calculated as follows:

$$ATET = \widehat{Y_1} - \widehat{Y_o} \quad (3)$$

where $\widehat{Y_1}$ is the average expected outcome for the treatment households, and $\widehat{Y_o}$ is the average expected outcome for control households obtained from the regression in Eq. 2 above.

Both the inverse probability weighting and regression adjustment components of the IPWRA model can be used individually for this type of impact analysis, but to produce consistent estimates, the former is dependent on the weights being correctly specified and the latter is dependent on the correct-specification of the regression model. However, the IPWRA model only requires one of the two to be correctly specified for the estimates to be consistent, therefore the model is classified as a doubly-robust estimator.

Tests of the effectiveness of the model indicate that we were able to further reduce the minor imbalances between treatment and control the households. For the variables used to weight the sample, the Standardised Mean Difference (SMD) was reduced from 0.09 to 0.07, and the Variance Ratio (VR) was reduced from 1.11 to 1.09.[4] To test the sensitivity of the results to model specification, the results were also verified using a secondary model based on a nearest neighbour PSM algorithm (Austin, 2011), which produced qualitatively similar results, suggesting that our findings are consistent across model specifications.[5]

[3] Control variables for each impact indicator were selected from the following list: Province; Location on irrigation canal; Distance from local market; Education of household head; Age of household head; Average age in household; Number of adults in household; Household size; Experiences drought/flood/pest outbreak shock in past year; Soil fertility; Hectares of land owned; Received training on rice production/water management/input subsidy; Received loan in past 12 months; Baseline asset index.

[4] An SMD of below 0.1 is recommended for a well-balanced sample (Austin, 2009).

[5] Results from this secondary model are presented in Appendix A.

4. Profile of the sample

Table 1 presents descriptive statistics on livelihood characteristics for the sample households in Regions VI and X. For both regions, average incomes are both well below the national average of PHP140,259, as well as the regional averages of PHP76,459 for Region VI and PHP120,799 for Region X (PSA, 2016). Although income and land use in Region VI are considerably lower than in Region X. Rice production is widespread amongst the sample but average harvests are larger in Region X and a much larger proportion of harvests are sold rather than consumed in this region.

Although poorer, the livelihoods of households in Region VI are more diversified compared to households in Region X, with the latter more dependent on rice sales. This diversity in Region VI may be survival, rather than opportunity based, given their lower incomes, lower land access, and higher risk of climatic shocks (Ellis, 2000; Svodziwa, 2018). Conversely, households in Region X may show signs of transformation in terms of the benefits they are gaining from specialising in rice farming, but they do not show signs of shifting into more lucrative on- and off-farm activities. They also seem to face barriers to their rice marketing, with further investigation finding that the majority of the rice sold by these farmers was unprocessed. Qualitative data from the region also highlights that CIS in the region are located far from local government offices and trading centers, a disconnection which may explain why their profile differs from their wealthier, cash-crop producing rural neighbours in the rest of the region.

5. Results and discussion

5.1. Agricultural production and income

Table 2 presents the results for IRPEP's impact on rice production per hectare, cropping intensity, production efficiency and rice sales in Region VI and X (the mean values for each of the impact indicators can be found in Appendix B). We find that rice yields were significantly increased in both regions, but more so in Region VI (13 per cent compared to eight per cent). However cropping intensity—measured by the proportion of operable land that was cultivated—was only increased in Region X and was significantly reduced in Region VI.

The efficiency of production—measured by the value of inputs including water user fees (but not including land) used to produce one tonne of rice—was only improved in Region X. Insights from the qualitative data suggest that efficiency of production was not impacted in Region VI due to farmers being unable to afford or access efficiency-enhancing inputs such as improved seed varieties, as well as their having to pay higher water user fees due to the strengthened collection capacity of the IAs. While the project encouraged this among the IAs to ensure the sustainability of the CIS, the sustainability of the project's impacts on livelihoods requires an increase in production efficiency to justify these costs, which does not seem to have occurred in Region VI.

Only in Region X did the project increase the proportion of rice harvest that was sold (by nine percentage points) and income from rice sales (by 128 per cent). In Region VI, further analysis finds that there was instead a significant increase in the proportion of harvest used to pay back costs incurred during production. Insights from the qualitative data suggest that this outcome was partially caused by farmers taking loans from local traders to fund their production, which then had to be repaid with their harvest.

The large impact on income from rice sales in Region X seems to have been driven by the increase in yields, rather than improvements in marketing. Qualitative data from Region X highlights similar issues of farmers being tied into credit-for-harvest arrangements with local traders, along with high transport costs and limited access to post-harvest processing machinery. IA leaders also reported that they have attempted to establish collective crop selling and value chain access for their members, but have failed due to farmers' persistent sale to local

Table 1
Livelihood characteristics of the household sample.

Land cultivated (ha.)	Region VI 1.7	Region X 2.3	Income ($/cap.)	Region VI 932	Region X 1348
Crops grown (% of sample):			Income sources (% of total):		
- Rice	99.8	100.0	- Rice sale	14.1	46.0
- Other	4.3	5.6	- Other crop sale	0.4	0.7
Rice harvest (t/ha)	3.3	3.7	- Waged labour	25.0	22.5
Proportion of rice harvest sold (%)	16.9	42.6	- H'hold enterprise	19.2	10.4
			- Livestock	7.9	4.0
			- Other (remittances, inheritance, etc.)	33.4	16.5

Table 2
IRPEP impact on agricultural production and sales.

	Harvest/ha.	Cropping intensity[†]	Input expt. per tonne of output	Per cent of harvest sold[†]	Rice sale revenue/ha	Obs
Region VI	13.31 %***	−12.48***	1.05 %	−0.12	−5.90%	441
Region X	8.08 %***	27.79***	−10.10%***	9.27***	127.50 %***	480

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively. Households not producing rice are not included in the model (Region VI = 26; Region X = 17).

[†] Coefficient represents a percentage point change.

traders based on traders' lower processing requirements and the credit and immediate payment they provide. In a similar vein, it was widely reported that the marketing support provided by IRPEP, which was not provided in Region VI, was largely ineffective for the same reason, and thus is unlikely to be the reason for the different impacts in the two regions.

We were unable to analyse the project's impact on crop diversity as very few households grew crops other than rice in the two regions, which implies that the project's impacts on agricultural productivity were restricted to rice production. For projects like IRPEP that are focused around the production of a single crop, it is expected that the economic benefits from specialisation counteract the potential increase in households' vulnerability to crop-specific shocks, however such benefits are only reflected in farm incomes in Region X.

5.2. Household income and livelihood composition

Presented in Table 3, we find a 19 per cent increase in income for households in Region VI, compared to a significant increase of just 0.4 per cent in Region X. This comes despite the lack of impact on rice sales in Region VI and the large impact in Region X shown in Table 2. The livelihood composition results in Table 3 show that there was a shift in both regions. These indicators represent the proportion of income composed from the different sources, and as they are themselves percentages, the impact estimates represent the change in the number of percentage points in the income composition for each source (rather than a direct percentage change). In Region VI, the share of income from crop sales reduced significantly by five percentage points compared to the control group, which reflects the reduction in cropping intensity noted above, while the share from the sale of livestock products and from off-farm waged labour increased by five and three percentage points, respectively. Additional analysis finds that livestock income per capita increased by 193 per cent in this region. In Region X, the share of income from crop sales increased significantly by 11 percentage points, while the share from off-farm waged labour reduced significantly by nine percentage points. We also find reductions in the share of income from livestock production and household enterprises, but these results are not statistically significant.

These results highlight the potential for opposing impacts of small-scale irrigation projects on livelihood composition based on context; impacts which can help or hinder the rural transformation process. Households in Region VI are poorer but with more diversified livelihoods, have restricted access to agricultural inputs, and are more at risk of climatic shocks. Livestock production is also a major part of the rural economy. IRPEP's impacts in this region indicate that the project helped to enhance households' already-diversified portfolio of activities, further reducing concentration on staple crop production and increasing the benefits from existing market linkages in livestock as well as off-farm waged activities—all signs of advancement in rural transformation at the household level.

The results in Region X have less positive implications. Here, although wealthier, households began with a restricted range of livelihood activities which the project seems to have entrenched. Although gaining somewhat from their specialisation in rice production, the marketing barriers they face mean that these gains have been insufficient to justify this concentration in terms of total household income—echoing past studies in the Philippines and India (JICA, 2012; World Bank, 2008). Livelihood concentration is usually driven by the prospect of significant gains from specialisation or due to a lack of opportunities to diversify (Freguin-Gresh et al., 2012). The relative poverty compared to the rest of the country of the beneficiaries in this region and the constraints to their rice marketing, along with the region's issues with connectivity and inequality, implies that their increased specialisation may be due to a lack of other opportunities.

Table 3
IRPEP impact on household income.

		Proportion of household income from:[†]					
	Total income per capita	Crop sale	Livestock	On-farm waged labour	Off-farm waged labour	Household enterprises	Obs
Region VI	18.65 %***	−5.12***	5.16***	−0.85***	3.28***	1.18	467
Region X	0.35 %***	11.44***	−14.06	−0.43	−9.00***	−1.66	497

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively.

[†] Coefficients represent a percentage point change.

Table 4
IRPEP impact on assets, nutrition, social capital and education.

	Productive asset index	Livestock ownership (TLU)	Dietary diversity score	Group meetings	Obs	School enrolment (% enrolled)[†]	Obs
Region VI	0.07**	1.10***	0.18***	3.95***	467	10.35	233
Region X	0.09	0.30	0.04	0.73	497	−2.74	260

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively.
[†] Coefficients represent a percentage point change. Note that the number of observations for school enrolment model is lower as the it only includes households with school aged children.

5.3. Assets, nutrition, social capital and education

Presented in Table 4, we find that ownership of livestock and of other productive assets increased significantly in Region VI. Dietary diversity, an indicator of nutrition, was also significantly increased, as was involvement in community groups, an indicator of social capital. Regarding education, we find a large positive but non-significant impact on enrolment, which may be linked to the low sample size (as the sample for this estimate is restricted to households with school age children). For Region X, we do not find significant impacts on any of these indicators.

The different impacts on these indicators in the two regions are seemingly linked to the larger impact on income in Region VI. In the qualitative interviews, households in Region VI noted that they used higher incomes from the project to purchase healthier foods and to send their children to school. In addition, the project's support to IAs may have also contributed to the impact on social capital. In the qualitative interviews, it was highlighted that the strengthened IAs in both regions helped to increase community engagement, although the lack of impact in Region X suggests that households may have faced additional barriers to improving social capital in this area.

These results also highlight important links between small-scale irrigation, livestock, and dietary diversity. In Region VI, we find livestock ownership and income to have increased, similar to findings from previous studies in Mali, Nepal and Vietnam (Dillon, 2011; ADB, 2012; Nguyen et al., 2017). Furthermore, enhanced livestock activities may have also contributed to improved dietary diversity in Region VI, as further analysis indicates that the project had a significantly positive impact on the consumption of both meat and eggs in the region.

5.4. Women's inclusion

Table 5 shows that the favourable impacts in Region VI also apply to women's inclusion in economic activities. In Region VI, we find a significant increase of four percentage points in the share of household income provided by women's income from waged labour and from household enterprises that they own (as with the livelihood composition indicators, this is a percentage indicator with impact measured in percentage points), and a significant increase of six per cent in the likelihood of a female household member owning their own enterprise.

For both regions, analysis of data collected from IAs also suggests that the project increased the number of women serving as IA officers. This impact could potentially have been mutually complementary to the impacts on women's economic inclusion in Region VI. Women's involvement in collective action groups can enhance their income generating capacity by increasing their economic opportunities and credit access, providing protection from risk, transferring knowledge and skills, and providing assistance in long-term asset accumulation (Pandolfelli et al., 2007; Quisumbing and Kumar, 2011; Schroeder et al., 2013). In-turn, the breaking of social norms achieved through autonomous income generation, more knowledge and assets, and increased strength in numbers can lead to increased representation and standing of women in their communities and households (FAO, 2011).

In Region VI, these results suggest that women were not excluded from the positive contributions of the project on rural transformation. Furthermore, women's increased economic activities may have contributed to the impact on total household income, and their increased income and bargaining power may have also fed into the positive impacts on education and nutrition. Conversely in Region X, women's economic opportunities do not seem to have changed, as part of the project's overall lack of influence on components of rural transformation in the region. While in Region VI, the expansion into livestock production and non-farm activities likely presented more opportunities for women to increase their income generating capacities, the increased focus on farm production in Region X may have restricted their activities to family farming (Slavchevska et al., 2016).

Table 5
IRPEP impact on women's empowerment.

	Women's wage and enterprise income (% of total) [†]	Likelihood of owning enterprise (%)[†]	Obs
Region VI	4.09***	5.54***	437
Region X	−3.67	−2.98	474

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively. Households where there are no women were not included in the model (Region VI = 30; Region X = 23).
[†] Coefficients represent a percentage point change.

5.5. Impacts by parcel location

There were significant positive impacts on rice yields and rice sale income for households that cultivated downstream parcels (Table 6). Respondents in the qualitative interviews attributed this mainly to better regulation of water use along the canals by IAs. Although the yield impact was very similar, households with up or midstream parcels had a much larger impact on rice sale income. Despite this, we do not find a significant impact on total income for either group. There was also no impact for either group on women's income, but there was a significant positive impact for downstream households on group meeting attendance. Not shown in the table is the impact for these households on income composition, for which the majority of income sources were not significantly impacted, except that the proportion of income from selling rice increased for up and midstream households.

Given their restricted irrigation water supply before the project, downstream households were expected to benefit relatively more from the project if they had the same amount of access to inputs as those further upstream. The similar yield impacts for the two groups thus implies input constraints may have hindered poorer downstream households from fully capitalising on the improved water supply, something that is supported by the qualitative data.

The smaller impact on income from rice sales for downstream households indicates that downstream households may also face greater obstacles to market access. The impact on income for up and midstream households echoes that for the wealthier households in Region X, whereby large rice income gains were counteracted by reduced involvement in other activities. However, the opposite effect was not found for downstream households as was found for the poorer households in Region VI, implying the diversification benefits for poorer

Table 6
IRPEP impact on up and downstream households.

	Harvest/ha.	Rice sale revenue/ha.	Obs	Total income per capita	Group meetings	Women's wage and enterprise income (% of total)[†]	Obs
Up/midstream	9.21 %**	148.67 %***	490	6.17%	−0.21	−3.45 (487)	514
Downstream	9.21 %***	30.56 %***	431	17.20%	1.67**	0.52 (424)	450

Note: Households not producing rice are not included in the model for the first two columns (Region VI = 26; Region X = 17).
*,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively.
[†] Coefficient represents a percentage point change.

households were specific to Region VI. The positive impact on social capital for downstream households without a significant impact on income suggests that this impact was driven by increased involvement of these households in communal activities of the CIS and IA, potentially due to the productivity benefits.

6. Conclusions and policy implications

This paper highlights the potential for user-managed small-scale irrigation to contribute to the rural transformation process, finding that strengthening such irrigation systems within an enabling environment can improve several of the components of the transformation process for smallholder farmers and rural women. This can help to accelerate the transformation process itself, as well as improve its inclusivity by supporting two groups who are most at risk of exclusion from the process.

In one project region that provided a supportive environment, we find that small-scale irrigation projects have the potential to contribute considerably to inclusive rural transformation. Before the project, households in Region VI were reasonably well-connected (living in a small but densely populated area), and the regional economy was structured to provide opportunities for rewarding livelihood expansion. In addition, due to exposure to frequent climatic shocks, the livelihoods of households in this region were characterised by diversification for survival and risk mitigation. For smallholders within this context, there is evidence that already-diversified livelihood activities can be enhanced and become more characteristic of the lucrative activities typical of a transforming rural economy. This impact on livelihoods comes particularly through fruitful links between irrigation and livestock, and is also reflected in more income generating opportunities for women.

In the other project region, however, less enabling local conditions led to limited impacts on the components of inclusive rural transformation. We find that, where smallholders' livelihoods are more static, and issues of connectivity, market access and unbalanced economic growth hinder livelihood expansion and value chain access, projects such as IRPEP struggle to contribute to inclusive rural transformation by themselves. In the worst cases, broader strategies to modernise the rural economy and to draw labour into more productive rural and urban sectors could even be hindered as smallholders become entrenched in existing livelihood activities and potentially become more vulnerable to shocks.

The finding that improved water supply and regulation can specifically benefit downstream households in terms of yields and on-farm income is promising, and highlights the benefits of supporting IAs to manage systems equitably. Broader livelihood benefits for these households, however, may be hindered by poverty-related obstacles such as limited access to inputs and markets.

Based on these results, if small-scale irrigation is to be used as a tool to promote inclusive rural transformation, it must be combined with strategies to foster complementary market linkages for smallholder farmers at the household level. These strategies must focus on building strong agricultural input and output markets (including financial markets) for these producers to access, and opportunities for them to expand livelihoods into more lucrative on- and off-farm activities. Without this, broader efforts to improve irrigation could cause smallholder farmers to be left behind in the transformation process by larger producers who are better equipped to take advantage of the benefits of improved irrigation. Particular attention is needed to ensure the inclusion of smallholder farmers located downstream, as well as rural women in farm households, who often face more obstacles to market access and inclusion (FAO, 2017). The strong link indicated by this paper between small-scale irrigation and livestock production among smallholders is surely an opportunity to capitalise upon in this case, given the rising urban demand for animal protein in developing countries (Henchion et al., 2017).

Regarding the specific components of inclusive rural transformation, we add further evidence supporting the link between irrigation and yields, with rice production increasing by 13 and eight per cent respectively in Regions VI and X. However, we note that improvements in production efficiency for smallholders can be hindered by input and credit access constraints, which can subsequently limit benefits from crop sales and make it hard for farmers to adjust to the higher user fees that they are now paying to the more effective IAs. In addition, we find that increased income and livestock ownership from improved irrigation can increase dietary diversity, consumption of livestock products, and social capital, with the latter also being improved through strengthened IAs. Finally, on the under-studied link between small-scale irrigation and women's empowerment for low-income rural households, we find that improving irrigation infrastructure and encouraging women's involvement in its management can considerably improve women's economic opportunities and their role in the community.

Our results also highlight the effectiveness of user-managed small-scale irrigation systems when IAs are provided with appropriate support. We find that these institutions can provide effective and efficient system management to the particular benefit of those located downstream and provide an avenue for women to gain greater responsibility and representation in the community. Based on our findings, an avenue for future initiatives could be to equip these institutions to provide further support to the livelihoods of system users in ways that address the input, market and credit access barriers that mitigated the impacts of IRPEP.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Impact results from the secondary NN model

Table A1. IRPEP impact from secondary model on agricultural production and sales.

	Harvest/ha.	Cropping intensity†	Input expt. per tonne of output	Per cent of harvest sold†	Rice sale revenue/ha	Obs
Region VI	8.89 %	0.35	8.97%*	−2.30	−37.24%	442
Region X	8.88 %	0.08	−9.55%	6.09***	41.31 %	480

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively. Households not producing rice are not included in the model (Region VI = 26; Region X = 17).

†Coefficient represents a percentage point change.

Table A2 IRPEP impact from secondary model on household income.

	Total income per capita	Proportion of household income from:†					Obs
		Crop sale	Livestock	On-farm waged labour	Off-farm waged labour	Household enterprises	
Region VI	36.67 %***	−2.66	0.12	−2.70	−0.66	12.41***	468
Region X	5.07 %	5.55	−2.98	2.16**	−4.84	−1.97	497

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively

†Coefficients represent a percentage point change.

Table A3 IRPEP impact from secondary model on assets, nutrition, social capital and education.

	Productive asset index	Livestock ownership (TLU)	Dietary diversity score	Group meetings	Obs	School enrolment (% enrolled) †	Obs
Region VI	0.14	−0.11	0.88***	1.78*	468	0.01	233
Region X	0.10	0.41*	0.09	0.52	497	−2.05	260

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively

†Coefficients represent a percentage point change. Note that the number of observations for school enrolment model is lower as the it only includes households with school aged children.

Table A4 IRPEP impact from secondary model on women's empowerment.

	Women's wage and enterprise income (% of total) †	Likelihood of owning enterprise (%)†	Obs
Region VI	0.44	6.78	468
Region X	−2.06	−4.02	497

Note: *,** and *** indicate that the estimated impact is statistically significant at the 10, 5 and 1% levels, respectively. Households where there are no women were not included in the model (Region VI = 30; Region X = 23).

†Coefficients represent a percentage point change.

Appendix B. Mean values of impact indicators

	Treatment mean	Control mean
Agricultural production and sales		
Harvest per ha (tonnes)	3.55	3.44
Cropping intensity (%)		
Total input expt per metric tonne of output (PHP)	145.97	143.11
Per cent of harvest sold (%)	33.23	30.97
Rice sale revenue per ha. (PHP)	438.96	403.42
Household income		
Total income per capita (PHP)	1142.70	1145.23
Proportion of household income from:	31.46	30.24
- Crop sale	5.98	8.29

- Livestock	2.18	1.85
- On-farm waged labour	20.19	23.93
- Off-farm waged labour	15.13	14.14
- Household enterprises		
Assets, nutrition, social capital and education		
Productive asset index	1.14	1.06
Livestock ownership (TLU)	2.38	1.58
Dietary diversity score	7.41	7.07
School enrolment (% of school age children enrolled)	93.41	91.50
Group meetings	6.25	5.50
Women's inclusion		
Women's wage and enterprise income (% of total)	15.95	18.46
Likelihood of owning enterprise (%)	17.93	18.06

Appendix C. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.agwat.2020.106437.

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