

# Water Works: The Economic Impact of Water Infrastructure

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## Abstract

Billions of hours are spent each year on water collection in developing countries. This paper explores whether improvements in water technologies, which decrease household distance to drinking water source and the time intensity of home production, enable changes in household time allocation and, thereby, productivity gains. Adults reallocate time towards leisure and labor on the household farm. Average yearly household cereals production increased significantly. Results imply a rate of return to labor equaling \$0.11/hour, approximately half the hourly farm wage. Absent evidence of improved adult health, results suggest that productivity gains were realized primarily through increased farm labor.

JEL: J22, O13, O53, Q12, Q25.

Keywords: environmental technologies, economic development, productivity, time allocation, water infrastructure

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# 1 Introduction

Processes of economic development are often accompanied by significant changes in within-household time allocation patterns.<sup>1</sup> Some have credited time-saving household technologies with reducing the time intensity of home production activities and increasing historical labor supply.<sup>2</sup> Empirical research supports the hypothesis that time-saving technologies have increased labor force participation in developed countries (Coen-Pirani, Leon, and Lugauer, 2010; Cavalcanti and Tavares, 2008). Technological progress in the household sector has been found to be more of a driver of such labor-force participation increases than wage increases. Simply put, “technological progress in the household sector erodes the value of labor in the home” (Greenwood et al., 2011). However, causality has proven difficult to disentangle. This paper uses quasi-experimental variation in access to domestic water infrastructure to provide causal estimates of how technological progress in household production can lead to productivity gains.

The context I explore is important. In developing countries, households without water infrastructure spend billions of hours collecting water for domestic use every year (Cosgrove and Rijsberman, 1998). This task is often designated to women. Given that water is necessary for life and used for numerous purposes beyond drinking, it is critical in household production. Lack of water infrastructure can drive up the time intensity of home production, thereby diverting time from potentially income-generating activities, such as formal work, agricultural labor, and small business activity (Harvey and Taylor, 2000; Blackden and Wodon, 2006). Advocates claim that the reallocation of these time savings are “one of the greatest returns to improved access to water” (Bjorkland et al., 2009; UNDP, 2006) and can “lay the groundwork for economic growth” (UN Millennium Project, 2005). Improvements in household technologies can help shift time allocation from basic household tasks related to water collection to increased market production, but the extent to which remains a question.

By analyzing a large-scale water infrastructure project implemented in rural Kyrgyzstan, this paper sheds light on the channels by which labor-saving water technologies may help decrease the time intensity of home production. The project’s stated objective was “to increase the supply and coverage of potable water to rural communities” with “time savings due to greater proximity to water collection points” listed as the primary expected benefit prior to

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<sup>1</sup>See Goldin (1995) for a discussion of the U-shaped relationship between development and female labor force participation.

<sup>2</sup>For example, there is evidence that technological progress in the United States during the 1900s, in the form of household time-saving products such as washing machines, vacuum cleaners, and frozen foods, contributed to cutting down the home labor and increasing the market work performed by women. As housework declined over time with the diffusion of new time-saving appliances, the participation of females in the labor-force increased (Greenwood, Seshadri, and Yorukoglu, 2005).

the project<sup>3</sup> (World Bank, 2001). I investigate the extent to which changes in household time allocation are aided by water infrastructure and can, in turn, change labor supply and productivity outcomes.

Rural households in northern Kyrgyzstan own six acres of land, on average, and the majority of working-age people are self-employed on their household's own small farm.<sup>4</sup> These households are labor-constrained, due to small family size<sup>5</sup> and low levels of mechanization (World Bank, 2007), a characteristic common of less developed countries. As of 2003, women in Kyrgyzstan cited home production to be the main reason (other than being in school or retired) for not participating in the labor market (World Bank, 2007). As a result, household members must carefully allocate their time between work in the market, work at home (which includes water collection, amongst other forms of home production), and leisure activities.

I use household-level panel data on agricultural inputs and production, along with individual-level 24-hour time budget diaries<sup>6</sup> to identify how both male and female household members re-allocate time saved after the construction of drinking water infrastructure. If people work more in the market, does this result in greater crop production? And if so, through which channels does the increased farm production occur?

Given the non-random placement of water supply systems in villages, it is possible that unobserved village-level characteristics, such as political connectedness, might be correlated with both water supply system placement and outcome measures. To isolate the effects of receiving water infrastructure, I use differences in the timing of construction across villages. This difference-in-differences approach controls for the unobserved, fixed characteristics of villages that might bias simple cross-sectional analyses.

When lacking water at their home, household members must bring water from other sources, either improved (wells, protected springs, shared standpipes and taps) or unprotected (streams, rivers, unprotected springs, lakes, irrigation canals). Rural households can require substantial amounts of time for water collection, as each round-trip from home to water source can be lengthy and multiple trips per day are required. The average time required per round-trip

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<sup>3</sup>Post-construction, an average of twelve households shared each water tap and in retrospective reports adults reported working more on their farms (DFID and World Bank, 2007). The second set of expected benefits were "health benefits resulting from reduced incidence of water borne disease, lower infant mortality rates, lower medical costs, less income loss from sickness, etc." (World Bank, 2001).

<sup>4</sup>This is based on calculations from the 1999 Kyrgyz Census.

<sup>5</sup>Since its 1991 independence, Kyrgyzstan's birthrate has decreased, resulting in smaller families (Dekker, 2003).

<sup>6</sup>Historically, there has been an absence of time budget diary data. Recall methods are considered less reliable, as respondents are not bound by a twenty-four hour constraint in recording their activities (Gronau, 1986) as they are with time budget diaries.

to collect drinking water in rural areas is 36 minutes in Sub-Saharan Africa and 23 minutes in Asia (United Nations, 2010).<sup>7</sup> Rural households in Kyrgyzstan similarly suffered from this time burden. Households that lack water infrastructure spent an average of 26 minutes per water collection trip (see Table 1). Of such households, approximately one-quarter spent between 30-40 minutes per trip and more than 10 percent spend more than an hour per trip (see Figure 1 for distribution) (UNICEF MICS, 2007).<sup>8</sup>

The proposition that labor-saving technologies can increase labor force participation is rooted in Becker’s model of household time allocation (1965). In Gronau’s (1977) model, which distinguishes between home production and leisure activities, a household will optimize where the marginal product of home production equals the market wage (Gronau, 1986). A key implication is that different technologies can decrease the value of time spent working at home, which increases the probability of market work (Blau, Ferber, and Winkler, 2002).

Evidence from developing countries similarly supports the proposition that shifts from home production to market work can result from certain household sector technological changes. Field (2007) found that improving property rights in urban Peru freed households from time previously spent protecting informal claims to the land. By not having to stay home to protect their property, households were able to increase the time allocated towards market work. Similarly, electrification in South Africa enabled males and females to increase their hours of market work, where fuel wood collection previously required two working days per week (Dinkelman, 2011).<sup>9</sup>

Each of the existing papers on the labor impacts of water infrastructure have found that access to water infrastructure results in less time spent collecting water; however, from there the results diverge. In urban Morocco, a randomized study found that shifting households from free neighborhood-level shared public taps to individual household connections did result in time gains; however, such time was re-allocated towards leisure and social activities (Devoto et al. 2012). The benefits of any water intervention will depend on the location, technology, and circumstances of implementation (Whittington et al., 2008); therefore it is understandable that market and non-market tradeoffs will differ between urban and rural contexts.

Three existing studies focus on rural households, all of which limit their analyses to females. Ilahi and Grimard (2000), the most similar in concept to my study, develop a household

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<sup>7</sup>These calculations were computed by the United Nations Statistics Division using data from Macro International, Demographic and Health survey (DHS) reports; Macro International, DHS STAT compiler; and UNICEF, Multiple Indicator Cluster Survey (MICS) reports (United Nations, 2010).

<sup>8</sup>Unfortunately, the MICS survey did not collect the number of water collection trips per day.

<sup>9</sup>Electrification impacted women’s intensive margin, working approximately 9 more hours per week.

model that is based on Becker (1965) and Gronau (1977). Testing the model with cross-sectional data for female household members in rural Pakistan, they find that time working on “market-oriented activities” decreases with distance between household and water collection point. However, the existence of unobservable household characteristics that are correlated with both distance of the water source and female labor participation may bias their results. Using a matched difference-in-difference method, Lokshin and Yemstov (2005) assess the impacts of multiple types of rural infrastructure projects, including water supply systems, in rural Georgia. With a limited sample of water projects, they find no significant impact of the water infrastructure on the share of working-aged women employed in wage labor. Koolwal and van de Walle (2010) perform a cross-sectional study utilizing data from nine developing countries to estimate the extent to which water infrastructure affects female labor force participation. The authors exclude farm self-employment from their measure of labor force participation and find no impact on women’s participation in market-based activities.<sup>10</sup>

This paper makes multiple contributions by adding rigorous empirical evidence on both the productivity and indirect impacts of water infrastructure to the existing literature on the labor market impacts of infrastructure construction in developing countries.<sup>11</sup> First, it utilizes detailed 24-hour time budget diaries, the data from which can be categorized into home production, market production, and leisure, permitting an analysis of time trade-offs, following the construction of water infrastructure. This provides insight on the value of time spent collecting water and thereby enables an informed cost-benefit analysis of the welfare impacts of water infrastructure. Second, using detailed data on farm and home production, in combination with the time use data, I estimate the aggregate productivity impacts of water infrastructure. This link between environmental technologies and productivity is understudied to date. Third, using village-level data on the incidence of water-related diseases, I evaluate the health impacts of shared public water taps to better understand the role of health in impacting time use patterns, both directly and indirectly.

Results indicate that households located in villages that received the water infrastructure are, on average, approximately 30% less likely to use an unprotected water source and 19% more likely to use a domestic water source that is less than 200 meters from their home. This reduces the time burden of water collection. Critically, having water closer to the house translated into time savings, with approximately 170 minutes less per day (on average) spent on home production. Less time is spent on activities that require substantial water collection, including activities related to care of one’s own physiology (e.g. time spent looking

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<sup>10</sup>They do, however, find impacts on children’s schooling and anthropometric z-scores for some countries.

<sup>11</sup>See Dinkelman (2011) for her point as to how this is a shift from primarily focusing on the “poverty, health, and education” impacts of physical infrastructure.

after oneself, bathing, and going to the doctor) and care of children (e.g. bathing and caring for them when sick).<sup>12</sup> Reductions in the time intensity of home production come with an average increase of 80 minutes per day in leisure activities and 90 minutes per day in farm labor.<sup>13</sup> Impacts are found for male and female time allocation; a logical result given males and females share water collection duties in this context. The additional farm work translates into significantly more cereals produced (barley and maize, specifically), which is critical for household income-generation.

I investigate the extent to which the water infrastructure might have impacted human capital and labor productivity via incidence of water-related diseases. Although the incidence of acute intestinal infections decrease by one-third amongst children, there is no evidence of such impact amongst the adult population. In addition, there is no significant impact on the average cereal production per hour worked on the farm. Together, these results provide no indication that adults are significantly healthier in the villages that received the water infrastructure. Taken together, results suggest that the main channel through which reductions in water-related illnesses affect adult labor is through their children. The time parents spend caring for children decreases when their children are sick less often.

Having shown that the water infrastructure increases both time spent working on the farm and production of crops grown on the farmland, I test the extent to which the increase in production is due to additional hours worked in the spirit of returns to capital estimates by de Mel, McKenzie, and Woodruff (2008). Instrumental variables calculations of the agricultural returns to labor indicate that each additional hour of labor allocated to the household farm produces approximately \$0.11 in cereals harvested. This estimated return to labor is approximately half the reported farm wage during this time period.<sup>14</sup>

Finally, I undertake a cost-benefit analysis of the water infrastructure. Lacking empirical evidence, many previous cost-benefit analyses are based on assumptions of the value of time spent collecting water (Whittington, Mu, and Roche, 1990). However, I can make an informed calculation by using the implied hourly farm wage of \$0.11 and by decomposing the time savings from home production (approximately 2.8 hours) according to where it is reallocated

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<sup>12</sup>A description of the time use categories is in Appendix Table 5.

<sup>13</sup>As described later in the paper, to determine whether the magnitude of the water infrastructure's effects on time reallocation is reasonable, I perform some basic calculations based on the principle that 50 liters are required per person per day to provide for basic drinking, hygiene, bathing, and laundry needs (UNDP, 2006). These calculations indicate that the water infrastructure could result in approximately 136 minutes per adult per day of time savings directly due to water collection, which does not include indirect sources of time savings. These calculations suggest that the magnitude of my results is plausible.

<sup>14</sup>The average hourly wage in 2003 for "market-oriented skilled agricultural and fishery workers" was \$0.19/hour (World Bank, 2007).

(approximately 80 minutes to leisure and 90 minutes to market labor). Just based on time reallocated towards farm work alone, the benefits are substantial: assuming a 12% discount rate,<sup>15</sup> the water infrastructure has a net present value of \$123 million<sup>16</sup>.

The remainder of the paper is organized as follows. Section 2 provides background information on drinking water access and labor in the Kyrgyz agricultural sector. Section 3 provides a conceptual framework of the links between water, time, and farm production. Section 4 addresses the empirical framework, including the identification. Section 5 explains the various datasets used in this research and baseline characteristics. Section 6 addresses the water infrastructure's impacts on time allocation, disease outcomes, agricultural production, and returns to labor. The cost-benefit analysis is described in Section 7. Section 8 concludes.

## 2 Background on Kyrgyzstan

According to the IMF's 2012 GDP (PPP) per capita rankings, Kyrgyzstan is ranked 147th (out of 187 countries) between Cambodia and Cameroon, and as such, is one of the world's 35 lowest-income countries. This section provides background on the baseline state of domestic water infrastructure and the role of agriculture for rural households in Kyrgyzstan.

### 2.1 Domestic water supply systems in rural Kyrgyzstan

While part of the former Soviet Union, some rural areas of Kyrgyzstan gained improved access to drinking water sources in the form of shared taps (also known as standpipes). However, the country saw marked decreases in the level of water supply services following the country's declaration of independence in 1991, with many of the existing water supply systems falling into disrepair. This left a large proportion of the Kyrgyz population drinking from sources contaminated by fertilizers, fecal matter, and other pollutants (USAID, 2006), such as irrigation canals, unprotected springs, rivers, or ponds. In the study regions, prior to the intervention approximately 50% of villages had no water service at all, 30% of villages provided service to 20-40% of households, and 15% of villages provided service to 41-60% of households (DFID and World Bank, 2007).

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<sup>15</sup>The 12% discount rate matches that used by the World Bank in the pre-project analysis.

<sup>16</sup>The cost-benefit was performed with different discount rates to provide a sense of the role that it plays in calculating the net present value (NPV). With a 10% discount rate, the NPV equals \$144 million and with a 8% discount rate, the NPV equals \$172 million.

## 2.2 Labor and agriculture in Kyrgyzstan

In Kyrgyzstan, the agricultural sector accounts for more than one-third of the country's GDP (World Bank, 2004) and on-farm growth has been credited as a driver for increases in non-farm goods and services (World Bank, 2007). The country's agricultural sector relies on the production of cereals, specifically wheat, maize, and barley (FAO, 2011). According to the 1999 census, 64.7% of the population of Kyrgyzstan, totalling approximately 3.14 million people, lives in rural areas. With 75.3% of the rural population over 15 years old working in agriculture (National Statistical Committee of the Kyrgyz Republic, 1999), a substantial proportion of rural households rely on sales of their farm products as their main source of income.

In the three provinces of interest (Naryn, Issyk Kul, and Talas), rural households have an average of 5.7 acres of land. This area is divided across an average of 2 plots of land, which typically include a home garden and a small farm (calculated from the 2003 Kyrgyz Integrated Household Survey (KIHS) data). There are several key differences between home gardens and small farms. A summary of the differences is presented in Appendix 1a. Home gardens tend to be small plots of land (between 0.1 ha to 2.0 ha in size) that are adjacent to the home, whereas the household's small (or "peasant") farm tends to be a larger plot of land that is located in the area surrounding the village.<sup>17</sup> Land on the small farms is three times more likely to be formally irrigated than land in the home garden (KIHS, 2003). Photos depicting these spacial differences are shown in Appendix 1b.

The potential income-generation of the plots is connected to the crops grown on each. Although 83% of home gardens are cultivated solely for household consumption, only 30% of farmlands are cultivated for solely household consumption (calculated from KIHS data, 2003). There are also several key distinctions in the allocation of crops grown on the two different types of land plots. Most fruits and nuts are grown in the home gardens. Vegetables may be grown in either the home garden or the small farm, depending on the type of vegetable. Fodder (grasses for hay) and cereals are grown almost solely on the small farms.

Small farms are constrained by low levels of mechanization and labor availability. The Kyrgyz farm sector has low access to capital equipment (World Bank, 2003) and existing equipment is old and inefficient (World Bank, 2007). Only 2.7% of rural households own any large agricultural equipment (including tractors) and only 9% own a horse (KIHS, 2003). Potentially due to the low levels of machinery, peasant farms require more labor per hectare than the

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<sup>17</sup>Following the independence of Kyrgyzstan, collective farms were sub-divided and allocated to residents in rural areas; most of land previously held by collective farms was shifted to peasant farms during in the process of land reform (Akramov and Omuraliev, 2009). This process of division led to the current distance from household to farm.

collective and state farms historically did (Dekker, 2003).

The farms are also constrained by the labor availability. Peasant farms primarily rely on family labor (Lerman, Csaki, and Feder, 2004); however since the 1990s, the birthrate has decreased, resulting in smaller families (Dekker, 2003). The median household farm in our sample is cultivating 100% of its farm land and not hiring any outside labor (KIHS, 2003). Labor constraints are particularly binding in the spring and fall months, when sowing and harvesting occur for the major food crops grown on the farms (FAO, 2011)

### **3 Conceptual framework of the links between water, time, and household farm production**

To understand the links between water, time, and agricultural production, one must understand how water infrastructure can impact the time intensity of home production. To do so, I consider a basic agricultural household model<sup>18</sup> in the spirit of Becker (1965) and Gronau (1977).<sup>19</sup> As in Strauss and Thomas (1995), households are assumed to maximize their utility from commodities purchased in the market and produced at home and leisure, subject to a budget constraint, time constraint, and home production function. A household must trade off between allocating time towards leisure, home production, and work in the market.<sup>20</sup>

This section provides a framework through which to understand these relationships and details on the water infrastructure introduced to alleviate the time intensity of water collection.

#### **3.1 Water infrastructure and the time intensity of home production**

In the context of this study, home production includes activities such as collecting water, performing housework (including cooking, washing dishes, doing laundry, sewing, cleaning the home, producing or buying food and non-food items, and other types of domestic labor), caring for one's own physiological needs (including bathing, looking after oneself physically, going to public bathhouses, going to the hospital or doctor, eating, sleeping, and other needs), caring for children (including time spent bathing, feeding, and caring for sick children, as well as helping them with homework and playing with them), and helping other relatives.

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<sup>18</sup>Singh, Squire, and Strauss (1986) thoroughly discuss agricultural household models.

<sup>19</sup>Of the previous work on the time impacts of water provision, two other papers, Koolwal and van del Walle (2010) and Ilahi and Grimard (2000), also examine such questions explicitly in the framework of such models.

<sup>20</sup>Throughout this analysis, I follow Gronau's (1977) distinction between time spent in home production and leisure.

Households lacking water infrastructure typically collect water for many purposes beyond drinking, such as preparing food, cleaning homes, bathing children, growing food in the family home gardens, and watering domestic animals (Schouten and Moriarty, 2003). As such, home production is more time intensive for households lacking water infrastructure in two ways. First, such households must collect the water for these domestic purposes and the collection takes time. Second, these households are limited by the water that they can transport to their homes and the constraints on water availability can make certain household activities, such as cleaning the home and washing dishes, more cumbersome and thus time intensive.

Given that households use the water for many domestic purposes, household members typically either make multiple water collection trips per day or send more than one household member to the water source.<sup>21</sup> The time required to make a roundtrip from home to water source and back depends on a few factors. First, distance from household to water source plays a large role. Water sources can be located a substantial distance from the house. Second, the physical characteristics of naturally-occurring sources (e.g. rivers and streams) and the surrounding terrain may increase the difficulty of and time required for collection.<sup>22</sup> Third, many households relying on the same source can result in crowding and queuing at the source.<sup>23</sup> As such, time required to collect water can be much greater than one would expect just based on distance to the source.

Water collection is often primarily a women's duty in many developing countries. However, based on data collected via the MICS survey, the duties of water collection tend to be shared between males and females in Kyrgyzstan. Overall, in rural communities in Kyrgyzstan, approximately 60 percent of households have females (women and girls) as their primary water collector. However, in the three provinces in which this study was implemented an opposite pattern exists (UNICEF MICS, 2006). Appendix 2 shows that in Issyk kul, Naryn, and Talas, approximately 60% of households have males as their primary water collectors. Therefore, in this context, lack of water infrastructure increases the time intensity of home production for both men and women.

Water infrastructure can address all of the constraints above by making water closer to the household, eliminating the risks of collecting from dangerous sources, and reducing the num-

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<sup>21</sup>For example, households in some areas of rural western Kenya make, on average, almost seven water collection trips per day to their water source (Kremer et al., 2011).

<sup>22</sup>For example, in Kyrgyzstan, children can fall into rapidly-moving rivers when collecting water, resulting in injury or sickness, particularly during the winter. Other sources may dry up late in the summer and fall, making it difficult to fill water containers.

<sup>23</sup>For example, Kyrgyz villages with water infrastructure at baseline had an average of 64 houses (but at times more than 200 households) sharing one tap (DFID and World Bank, 2007).

ber of households queuing at a collection point. To address the lack of water infrastructure in rural Kyrgyzstan, a large-scale effort was launched in the early 2000s to construct water infrastructure, in the form of shared water taps, to rural communities. Villages were informed of the project and, if interested, they applied to receive the infrastructure. Given that there was not enough funding to provide all villages with the infrastructure, a village selection process was carried out annually between 2003 and 2006. Of the 255 villages that were eligible for the program, 194 were selected over four years to receive the water infrastructure. The phased-in the selection process, which provides our identification source, is mapped in Appendix 3.

### **3.2 Alternative time uses: leisure and market work**

The decreased time intensity of home production frees time for leisure and market work. Leisure includes activities such as listening to the radio, playing sports, spending time with friends, and reading, amongst others. Market work is the potentially income-generating labor, which in this context is predominantly work on the household's own small farm, but also includes formal employment that earns a salary (teachers, government employees, and health care workers), and entrepreneurial activities, trade, and other informal employment.

The average household is approximately 5 people, which is relatively small given that households have an average of 6 acres of land (KIHS, 2003). As a result, households are labor-constrained. Ex ante it is not obvious how households will reallocate time savings from the reductions in the time intensity of home production. This paper tests the extent to which time is reallocated to either leisure or market work.

## **4 Empirical Framework**

To isolate the impact of the water infrastructure, I utilize the phased-in timing of the village selection process in conjunction with panel datasets of villages, households, and household members.

### **4.1 Identification strategy**

I estimate the impact of a village being allocated a water supply system on individual time use and measures of household agricultural production. A simple cross-sectional analysis of the difference between villages that receive and villages that do not receive the infrastructure is likely to be biased due to unobserved, confounding variables. Given the phased-in selection

of villages over several years, I use the differences across villages over time to estimate the impact of being allocated a water supply system on these outcome measures. This allows me to control for the unobserved, fixed confounders that are correlated with both access to water and outcome measures.

First, I test whether village selection improved household water access by decreasing household use of unprotected water sources, increasing household use of shared standpipes, and decreasing the distance between households and their domestic water sources. All regressions include village fixed effects (to account for the time-invariant village characteristics) and district-year fixed effects. Many of the outcome measures (e.g. crop production, time allocation, and even measure of health) are impacted by rainfall, which has tremendous variation spatially. District-year fixed effects will absorb much of the variance in weather, thereby allowing us to isolate the impact of the water infrastructure.

The difference-in-differences estimate of the water infrastructure's impact is calculated through the following equation:

$$S_{hijkl} = \beta_0 + \beta_1 w_{jkl} + \Gamma' d_{hijkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihijkl} \quad (1)$$

where  $S_{hijkl}$  represents the three indicators of water access, specifically use of an unprotected water source, use of shared standpipes, and distance of the water source of household  $h$  in village  $j$  and district  $k$  in year  $l$ ;  $w_{jkl}$  indicates whether village  $j$  was allocated a water supply system two years prior;  $d_{hijkl}$  is a vector of household-level controls;  $(\alpha_k * \delta_l)$  represent district-year fixed effects; and  $\theta_{jk}$  are village fixed effects.

After showing that the project improved water access, I estimate the impact of the infrastructure on individual-level time allocation. The difference-in-differences estimate of the impact of the water supply system construction on individual time use is obtained through the following OLS regression:

$$T_{ihijkl} = \beta_0 + \beta_1 w_{jkl} + \beta_2 d_{hijkl} + \Pi' x_{ihijkl} + \Omega' z_{ihijkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihijkl} \quad (2)$$

where  $T_{ihijkl}$  is the number of minutes in a 24-hour period individual  $i$  of household  $h$  in village  $j$  and district  $k$  allocated towards a given activity in year  $l$ ;  $w_{jkl}$  indicates whether village  $j$  in district  $k$  was allocated a water supply system two years prior to year  $l$ ;  $d_{hijkl}$  refers to the size of household  $h$ ;  $x_{ihijkl}$  is a vector of individual-level controls, including age and gender; and  $z_{ihijkl}$  is a vector of interview round controls, such as season and day of week on which the data were collected.

Similar to equation (1), the following regression estimates the impact of drinking water infrastructure on household agricultural outcomes, such as crop harvests:

$$A_{hijkl} = \beta_0 + \beta_1 w_{ijkl} + \Gamma' d_{hijkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihijkl} \quad (3)$$

where  $A_{hijkl}$  is the amount harvested by household  $h$  in year  $l$  of a particular crop (or group of crops), as measured in kilograms; and  $d_{hijkl}$  is a vector of household-level controls, which in this case also includes household farm characteristics, such as the total plot size, the proportion of land irrigated, the number of land plots owned by the household, proportion of cultivated land, and household expenditures on farm-related things.

## 5 Data

This paper relies on data at the household- and individual-level, as provided by the Kyrgyz Integrated Household Survey (KIHS), and village-level, as provided by the Kyrgyz National Census and the Ministry of Health data. All data sources are described below.

### 5.1 Village selection process

The villages that applied for the water infrastructure were judged based on four factors: (1) need for water, (2) poverty levels, (3) economic and technical feasibility, and (4) community participation.<sup>24</sup> Selection occurred annually between 2003 and 2006, resulting in 194 villages being chosen. Maps and a written description of the phased-in process across space over time are in Appendix 3.

Data on the village selection process were provided by the Kyrgyz Ministry of Water. Data on village selection include the villages selected to receive water infrastructure, the date of selection and date of registered construction completion. Calculations indicate that the average length of time between village selection and this official completion date is approximately two years. The distribution of the time between selection and water supply system completion for villages is shown in Appendix 4. The official date of water supply system completion does not reflect when households began to use the system. Therefore, I assume a two-year lag between selection and construction completion in all analyses.<sup>25</sup> The data on village selection are

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<sup>24</sup>To ensure the process was not manipulated for political reasons, the selection process was done by a panel representing government agencies and international organizations.

<sup>25</sup>To ensure the robustness of this assumption, I calculated results showing the impact of the project on

then matched with the village-level census data, village-level data on water-related diseases, household-level data on agricultural production and other household characteristics, and the individual-level data on time use.

## 5.2 Kyrgyz Integrated Household Survey

The Kyrgyz Integrated Household Survey (KIHS) was implemented annually by the Kyrgyz National Statistics Committee between 2003 and 2010, providing household-level data. The KIHS is a rotating panel, with one-quarter of the households changing each year. The sampling method employed for the KIHS is a two-stage stratified design. From the 1999 census, primary sampling units (PSUs) were identified. Stratifying by province and whether the location is rural or urban, 456 PSUs were randomly selected.<sup>26</sup> Importantly for this study, PSUs have primarily remained the same between 2003 and 2010. Within the 3 provinces, 66 rural PSUs were surveyed; 38 of which applied to the project and of those 24 received the water infrastructure. Household-level data from these rural PSUs create a panel dataset of approximately 420 households annually surveyed between 2003 and 2010.<sup>27</sup>

The KIHS collects data on households and their members, including information on household characteristics and consumption and individual education, health, and employment. Given the large proportion of rural households that survive on agricultural production on their small farms, the survey collects quarterly agricultural data, such as crop production, land characteristics, and expenditures on farm-related activities.

Additionally, in 2005 and 2010, the KIHS included a module on time use, through which individuals kept 24-hour time use diaries. The diaries were timed such that all days of the week were represented proportionally. Individuals 12 years and older were asked to record their time use for a twenty-four hour (1440 minutes) period. Appendix 5 shows the different categories of time use. There is, however, no category specific to water-collection, so water-related time use accrues to the category in which the activity is associated. For example, if water were collected for cleaning one's home, then that time would be recorded as housework. Collecting water for bathing or for livestock kept in the family's garden would be recorded as self-care and working with in the home garden, respectively.

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water access for both the two-year lag and the government date of completion. Results from the two methods are very similar.

<sup>26</sup>In rural areas, a PSU is equivalent to a village.

<sup>27</sup>Within the PSUs, households were randomly selected, with a probability proportional to village size.

### 5.3 Village-level data

The Kyrgyz National Statistics Committee and the Kyrgyz Ministry of Health State Sanitary Epidemiological Surveillance (SSES) provided village-level data collected on village characteristics and disease incidence, respectively. Census data are collected once a decade and are available for 1999 and 2009, providing village-level characteristics for one period prior and one following the water intervention. Such data include population size, average household size, education levels, income sources, and the proportion of population self-employed.

Annual village-level data were collected on incidences of two water-related diseases over the period of 2000 to 2009: Hepatitis A and acute intestinal infections.<sup>28</sup> These data were collected by SSES via village-level health facilities. Incidence of each disease per 100,000 people was calculated based on yearly village population estimates.

Using data reported through the government health system provides both advantages and disadvantages. These government-collected data provide a strong alternative to self-reported incidence of disease and mortality. Some experts on the topic have expressed concern regarding the strength of studies relying on self-reported child diarrhea (Schmidt and Cairncross, 2009) collected through surveys, as frequent surveying may lead to respondent fatigue, social desirability bias, and health protective behaviors (Zwane et al., 2010). These factors could potentially impact individual responses and potentially bias results. In contrast, the village-level health outcomes collected through village health-care providers are less susceptible to such biases.

The village-level health data utilized here may be subject to other biases. It is possible that the villages without health facilities are smaller or more remote than those with such facilities, and therefore poorer. If this is the case, then the poorest populations are excluded from this part of the study, as there would be no data on the incidence of water-related diseases for these locations. A few of the existing studies addressing heterogeneity of impacts indicated that poorer populations might be impacted differentially than those that are better off (Jalan and Ravallion, 2003; Galdo and Briceno, 2005; Galiani, Gertler, and Schargrodsky, 2005); however, there is no agreement as to the direction of that effect.

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<sup>28</sup>The SES definition of acute intestinal infections includes dysentery, giardia, enterobaecces, acariasis, and acute viral hepatitis.

## 5.4 Baseline characteristics

Baseline characteristics are calculated using the 1999 village-level census data. Column 1 of Table 2 shows that the average village in that group had 1,676 residents across approximately 338 households, averaging 5 people per household. The average village reported that 52% of households receive income from forms of self-employment and 56% of adults had completed at least secondary school.

Comparing the baseline characteristics of villages that received a water supply system (column 3) with those that did not (column 2), the two groups are statistically significantly different only with respect to the number of households and the average household size. The latter tends to be positively correlated with higher poverty levels; as indicated earlier, poverty was one consideration in village selection.

## 5.5 Testing parallel trends

The difference-in-differences estimation strategy uses differences in the timing of infrastructure construction across villages over time. This empirical strategy is based on the identifying assumption that, in the absence of the water infrastructure construction, the villages selected early and those selected later would have changed similarly in the absence of the program. I test this “parallel trends” assumption using household-level data for 2003-2004, the period prior to infrastructure completion. Column 8 of Table 3 shows that no statistically significant differences in trends exist between the two groups pre-intervention. This is true for household-level water access (as shown in Panel A), agricultural production (shown in Panel B), as well as small farm characteristics (including farm-related expenditures, which will serve as control variables).

Time use data were collected via the KIHS in 2005 and 2010. The program villages that were selected in 2003 are considered “treated” as of 2005, meaning that there is no pure pre-infrastructure baseline data for time use. For this reason, I cannot test the parallel trends assumption with respect to time use.

# 6 Impacts of Drinking Water Infrastructure

## 6.1 Water access

Results shown in Table 4 indicate that the project worked; households in villages that were allocated water infrastructure are more likely to use shared piped water and less likely to use

unprotected sources for their main water supply. Importantly, these households are approximately 19% more likely to have their water source less than 200 meters from the household.

## 6.2 Time allocation

In order to understand the overarching reallocation of household time that comes with water infrastructure construction, I first estimate equation (2) with all time used within the 24-hour period aggregated into one of three categories: leisure, home production, and market work. To do so, time use is aggregated in the spirit of Gronau (1977) and his distinction between leisure and home production. Analyzing the impacts on time use within a 24-hour period permits the measurement of the complete reallocation of time. An analysis at this level of aggregation is possible only due to the nature of the time budget diaries (and that data cover the full 24-hour period). Results of these Gronau-style regressions are shown in Table 5. As expected, the water technology decreased the time intensity of home production. Column (1) shows that home production decreases by approximately 2.8 hours following the introduction of the water infrastructure. Columns (2) and (3) show how this time is reallocated, with approximately half (90 minutes) going to market work and half (80 minutes) to leisure. With a significant proportion of the time savings is reallocated towards leisure, this result is consistent with Devoto (2012). These results indicate that the water infrastructure is freeing up time that people are then able to reallocate towards other productive labor. Taken together, these results are consistent with the belief that households are labor-constrained and are trading off between work in the market and home production.

A more nuanced understanding of this time reallocation is provided in Table 6,<sup>29</sup> which shows, for males (Panel A) and females (Panel B) separately, the impacts of water infrastructure on sub-categories of market work and home production. The main areas of time savings occur in home production, including work in the home garden, caring for children, and self-care. Only a very small proportion of home gardens are formally irrigated (KIHS, 2003). Given the crop production and livestock living in the garden (Currey, 2009), home production activities occurring within the home gardens require substantial water. Work in the home gardens is less time intensive post-construction, as it is less challenging to collect water for garden plants and livestock kept within the gardens.

Adults may spend less time caring for children if they are sick less; we see reductions for both males and females, although neither are significant. And caring for oneself (Column 7) is significantly less time consuming, as bathing and taking oneself to the doctor require less

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<sup>29</sup>Column 8 shows impacts on leisure and matches the results on the same in Table 5.

time following infrastructure construction. These results are similar for both men and women, albeit the magnitude of the impacts on self-care is substantially larger for women.

Columns 1 through 4 of Table 6 show how time is reallocated within market work. Men and women reallocate approximately 116 and 90 minutes to farm labor, respectively. When we account for reductions in other forms of women's market work (Columns 3 and 4) their total additional market work sums to approximately 50 additional minutes. Interestingly, women also report, on average, an increase in time spent en route to and from their market work. This could reflect more frequent trips to the household farm.

### 6.3 Water-related diseases

Using data on village-level incidence of water-related diseases, I investigate whether the water infrastructure led to improved health. Acute intestinal infections and Hepatitis A are two such water-related diseases. If either adults or children are healthier due to the water infrastructure, one would expect incidences of these diseases to reflect as much. Table 7 shows results per 100,000 people for two age groups: children 0 through 14 years old (Panel A), and adults aged 15 and older (Panel B). In columns (1) and (2), results indicate reductions occurred in village-level incidence of acute intestinal infections, albeit, only for children. The preferred specification (in Column 1) indicates that acute intestinal infections amongst children fell by approximately one-third.

Additionally, I check to see whether households in villages that received the water infrastructure produced more cereals per time worked on the farm. Although the relationship is positive, there is no statistically significant increase in this measure of labor productivity. Taken together, these results indicate that the primary channel through which water-related diseases affect adult labor is through time; children are healthier and therefore parents allocate less time to their care.

### 6.4 Agricultural production

If labor is a constraint in agricultural production and farm labor increases with water infrastructure construction, one might also expect an increase in farm production. I test whether households in treated villages, on average, have greater crop production from their farms following infrastructure construction. To do so, I focus on the crop groups that are grown solely on the farmland (fodder and cereals) and regress the log production of these crops on the indicator of water infrastructure construction.

Results in Table 8 indicate that the reallocation of time towards market work, and time on the household farm in particular, comes in conjunction with greater production of crops grown on farmland. There is a substantial, albeit insignificant increase in cereal production. Results in columns 3 through 6 show the types of cereals in which the largest gains occur. Production of barley and maize increase by 36 and 107 percent, respectively.

Based on worldwide quantities produced, maize and barley are the two most important coarse grains<sup>30</sup> (FAO, 2009). Barley, which can survive droughts, low temperatures, high altitudes, and poor quality soils, suits the climate in Kyrgyzstan. Barley is used for both livestock feed and human consumption. In Kyrgyzstan, both spring and winter varieties of barley (and wheat as well) are grown. Because it is a fast-growing crop, multiple plantings of barley can occur during a single calendar year (FAO, 2011).

The median farmer in our sample reports cultivating 100% of his farmland at baseline. One way to increase crop production would be for farmers to increase the number of plantings within a given year, which is possible for crops with winter and spring varieties. However, the demand for labor is seasonal and peaks in the fall months, which are crucial for harvesting the spring varieties and sowing the winter varieties of both wheat and barley. Maize is also harvested during this time. The timing of sowing and harvesting these crops is shown in Appendix 6, making clear the time constraint for farming households during the late summer and early fall. In conditions in which two or more crops are grown on the same field in a year, peak season labor scarcity can be particularly exacerbated when, for example, the peak demand for harvesting labor for one crop occurs near simultaneously with the greatest labor demand for land preparation and seeding of the other crop (Pingali, 2007).

## 6.5 Returns to additional farm labor

Thus far, results indicate that the infrastructure brought water supplies closer to households, decreased the time required for water collection, increased the time spent working on household small farms, and increased farm production of cereal crops. Next, I estimate the extent to which the additional farm production is the result of additional hours of farm work, to better understand the channel through which domestic water infrastructure might affect agricultural production. These calculations are analogous to the returns to capital calculated by de Mel, McKenzie, and Woodruff (2008). Specifically, I estimate the effect of the additional time spent working on household farmland on the production of cereals and fodder, the crops solely grown

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<sup>30</sup>Coarse grains includes cereals such as maize, barley, oats, and sorghum, but exclude wheat and rice (FAO, 2009).

on farm land. This calculation uses construction of water infrastructure as an instrument for the time allocated toward farm work. This provides the local average treatment effect (LATE).

To perform these calculations, I match data from the KIHS agricultural production and expenditures modules, data from the time use module (available only in 2005 and 2010), and data on agricultural land. This analysis is limited to the years in which data from all modules overlap (2005 and 2010), which results in a sample of 635 households across 37 villages.

The first-stage estimates the difference in total household time allocated toward farm labor in villages that receive the water infrastructure and is calculated through the following equation:

$$T_{hijkl} = \beta_0 + \beta_1 w_{ijkl} + \beta_2 d_{hijkl} + \Omega' z_{hijkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{hijkl} \quad (4)$$

where  $T_{hijkl}$  is the total amount of time (number of minutes out of a total of 1440 minutes per day) the household spent working on their small farm.<sup>31</sup> The second stage equation then estimates the increase in cereal production that results from the additional time of farm labor:

$$A_{hijkl} = \beta_0 + \beta_1 T_{hijkl} + \beta_2 d_{hijkl} + \Omega' z_{hijkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{hijkl} \quad (5)$$

where  $A_{hijkl}$  is the amount of cereals harvested by household  $h$  in district  $j$  year  $l$ , as measured in kilograms;  $w_{ijkl}$  indicates whether village  $j$  in district  $k$  was allocated a water supply system two years prior;  $T_{hijkl}$  is the total number of minutes of time allocated in one day towards working on household  $h$ 's farm by all individuals 12 years and older in household  $h$ ;  $z_{hijkl}$  is a vector of interview controls, specifically the season and day of week on which the household members were interviewed;  $d_{hijkl}$  is a vector of household-level controls including household size and the number of dependants/pensioners in the household, and farm characteristics, such as the total plot size, the proportion of land irrigated, the number of land plots owned by the household, proportion of cultivated land, and household expenditures on farm-related things; and  $(\alpha_k * \delta_l)$  represent district-year fixed effects; and  $\theta_{jk}$  are village fixed effects. All standard errors are clustered at the village-level.

Analogous to de Mel, McKenzie, and Woodruff's (2008) calculation of the returns to capital, I estimate the returns to the additional farm labor in both levels and logs (representing the linear relationship and constant elasticity of substitution, respectively) and instrument for the additional farm labor with whether the village received the drinking water infrastructure. For the instrumental variables estimation to be valid, the exclusion restriction must hold and

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<sup>31</sup>There are 3.4 workers per household (on average) in this sample. In comparison, the average household size is 5.1 people. This difference between the average household size and the average number of workers is due to children under 12 years old in the household.

receiving the water infrastructure must only change the cereal production through the hours worked on the farm, not through the other farm inputs.

The obvious concern is that households may use the drinking water to irrigate the crops grown on the farms and that could lead to greater farm production. I rule out the possibility that the domestic water is used for irrigating households' farmland and therefore impacts farm productivity through direct water supply. There are several facts that support this assertion. First, almost all land used for the small farms is irrigated in some fashion, whether by the old Soviet irrigation infrastructure or by less permanent earthen canals (KIHS, 2003). Thus, the small farms do not necessarily need the domestic water. Second, as shown in Appendix 1b, most of the household farms are actually located a substantial distance from the home (Currey, 2009) and are on the outskirts of each village,<sup>32</sup> making the domestic water infrastructure an extremely inconvenient and unlikely farm irrigation source. Households are therefore unlikely to use domestic water to irrigate their farm plots. As an additional check, I test whether the drinking water infrastructure has any impact on the amount households pay in irrigation fees (results not shown) and find that it does not.

In other farm contexts, farmers have been found to shift complementary inputs (such as herbicides and hired labor), when they receive fertilizer (Beaman et al., 2013). To ensure that in this setting farmers are not shifting inputs complementary to farm labor, I check whether other farm inputs changed upon receipt of the drinking water infrastructure. Results shown in Appendix 1C, do not show any such evidence.

As shown in Table 9, the additional farm labor that results from the water infrastructure leads to an additional 3.56 kg of cereal crops harvested. This equals an hourly wage of approximately \$0.11 per hour, which is roughly half the reported hourly farm wage.<sup>33</sup> In an effort to isolate the impact of farm labor on farm-grown crops, I only include cereal and fodder production in the calculations of the returns to labor. These calculations omit the effort the additional labor might have had on other crop groups and therefore provide a lower bound for returns to labor.

These results contribute to the empirical literature testing models of household decisions and separation between the household's production and consumption decisions.<sup>34</sup> According to the standard agricultural household model, the farm's production should be determined by

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<sup>32</sup>This is as a function of how the collective farms were divided amongst the village households when Kyrgyzstan declared independence from the Soviet Union.

<sup>33</sup>The World Bank (2007) reported \$0.19/hour as the wage for market-oriented, skilled agricultural and fishery workers.

<sup>34</sup>Singh, Squire, and Strauss (1986) and Strauss and Thomas (1995) provide discussion of the recursive property. See Pitt and Rosenzweig (1986) and Benjamin (1992) for examples of tests of separation.

market wages and technology, not by the household’s consumption. If labor in the market and home are perfect substitutes, then the household optimizes by allocating labor such that the marginal product of home production equals the market wage (Strauss and Thomas, 1995). The \$0.11 per hour that I estimate is approximately half the wage of skilled hired farm labor. A number of studies have found evidence of non-substitutability between household labor and hired labor; however, the result of those studies indicate a shadow price of household labor approximately double the shadow price for hired labor (Roumasset and Lee, 2007). In this case, the price of household labor is estimated to be far less than the reported price for hired labor. It might be that the wage for unskilled labor is something closer to the estimated \$0.11 per hour. If that is the wage at which households value their own labor, then the difference is explained. However, as described in Benjamin (1992), the separation property might not hold if certain markets are incomplete. In our sample, the median farmer is hiring no outside labor, suggesting that the labor markets in these contexts are indeed incomplete. Shortages of labor are expected in areas in which the population is sparse or good nonfarm labor opportunities exist (Pingali, 2007). In rural Kyrgyzstan, the former is the case.

## 6.6 A cross-check of time savings

To determine whether the magnitude of the water infrastructure’s effect on time reallocation is reasonable, I perform some basic calculations. According the Human Development Report 2006, 50 liters per person per day are required to meet the needs of drinking, basic hygiene, bathing, and laundry (UNDP, 2006). With the average household size of 5.2 people (per the 1999 Kyrgyz census), the average household requires 260 liters per day. Assuming that a single person can carry 20 liters (which weighs 20 kgs) in a trip from the water source,<sup>35</sup> then 13 person-trips per day are required to collect enough water for the entire household.<sup>36</sup> Given that the majority of households in my study regions report that an adult (either male or female) is their primary water collector (UNICEF MICS, 2007), I assume that the time spent collecting water is divided by two adults. The average time for water collection is 26 minutes round-trip for households using unprotected water sources (based on calculations using the UNICEF MICS (2007) data), resulting in water collection requiring 338 minutes per household (or 169 minutes per each of the two adults) per day at baseline. Once a village receives the water supply system, I assume that a round-trip for water collection is reduced to 5 minutes per trip, equalling 65 minutes per household (or 32.5 minutes per adult person) per day. These time savings estimates, which include only direct benefits from water collection, equal 136 minutes per adult per day. Given our estimates based on the KIHS include both

<sup>35</sup>This assumes that households are not using livestock to carry more than 20 liters per trip.

<sup>36</sup>How this is carried out could vary widely. For example, there could be 13 trips by one person in the household or multiple trips by a few people in the household.

direct and indirect benefits, this back-of-the-envelope calculation supports the argument that these results fall within a reasonable expected range.

## 7 Cost-benefit Analysis

From a policy perspective, it is important to understand the welfare consequences of the infrastructure. To do so, I perform a cost-benefit analysis in which I assume the water infrastructure has a lifespan of 20 years, per the World Bank's analysis (World Bank, 2009).

The costs of the water infrastructure include the upfront costs for the infrastructure construction, which totalled approximately \$24 million, and ongoing maintenance costs. The upfront costs were comprised of a loan from the World Bank (\$17.99 million)<sup>37</sup>, an upfront contribution from the Government of Kyrgyzstan (\$3.2 million) and a 15% labor contribution (\$2.99 million) from the villages. I use data on the monthly budget for village water tariffs as the measure for on-going maintenance costs, which equal approximately \$560,000 in the first year and are assumed to increase by 2% each year throughout the 20-year life of the water infrastructure. Using a 12% discount rate results in costs of approximately \$28.19 million.

In calculating the benefits, I include only the benefits from the time savings for adult beneficiaries. This is due to the lack of time use data for children. This provides a lower bound of the infrastructure's total benefits, as it omits non-time benefits for adults and all benefits for children, such as reductions in incidence of water-related diseases and improved school attendance.

To estimate the benefits, I assume the time savings begin at the time of construction completion (which is, on average, two years after village selection occurred). I assume the time savings accrue for the 20 year life of the water supply system. To count the number of people benefiting from the project, I calculate the baseline total working-age adult population for all of the villages that received water infrastructure through the project, based on the 1999 census. Although this population will presumably grow over the twenty-year period, I assume that the infrastructure can serve only the population size at construction completion and therefore assume a constant population of project beneficiaries throughout the life of the infrastructure.

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<sup>37</sup>Here, for ease, I am assuming that the entire value of the loan is a cost incurred at the project outset. However, I have also performed the analysis under the specific financial conditions of the loan (which are 0.75% for 40-year period with a 10-year grace period). The specific choice of analysis depends on whether one is analyzing the project from the lender's perspective or that of the borrowing country. For a cost-benefit analysis, my current approach is the more conservative alternative, as costs are upfront and therefore not discounted.

As discussed in Whittington, Mu, and Roche (1990), a dearth of data on how people value time spent in water collection has made it challenging to value the time savings that result from water infrastructure. Using a discrete choice model to analyze household decisions in a region of Kenya, they found that households value the time spent on water collection at roughly the value of the unskilled wage rate (Whittington, Mu, and Roche, 1990). However, in practice, cost-benefit methods typically either assume time savings to be valued at a percentage of the market wage rate for relevant unskilled labor or they specify a proportion of time saved that is assumed to be spent in market production.<sup>38</sup> I do not have to make such assumptions. The Gronau-style regressions (as presented in Table 5), permit the decomposition of time savings according to time reallocation. Results indicate that time in overall home production decreases by approximately 3 hours per day, and of that time saved, approximately 80 minutes are reallocated toward leisure and 90 minutes towards market work.

To estimate the benefits of the water infrastructure, I use an hourly wage rate of \$0.11, as estimated through the returns to labor calculations.<sup>39</sup> This is multiplied by the total working-age population benefiting from the project, as discussed above. Future benefits are assumed to accrue for the 20-year life of the infrastructure and are discounted assuming a 12% discount rate.<sup>40</sup> This results in estimated benefits equaling \$232.2 million. Finally, I assume that farm labor only occurs for three quarters of the year (spring through autumn). This results in estimated benefits of approximately \$174 million. As a lower bound, I can calculate the benefits including only those hours reallocated to market work, which results in estimated benefits of \$92.3 million.

Calculating the benefits of rural water supply systems solely on time reallocation, I find that the benefits substantially outweigh the costs. Based on the above calculations, the net present value of the water infrastructure is between \$64.1 million and \$145.9 million.<sup>41</sup> This analysis suggests that even in contexts in which health benefits are ambiguous, the time use benefits alone may justify the infrastructure.

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<sup>38</sup>For example, the pre-project cost-benefit analysis for this project assumed that half the time saved could be reallocated toward “commercially productive uses” (World Bank, 2001).

<sup>39</sup>I assume this grows at 2% per year.

<sup>40</sup>This is the discount rate that was used in the pre-project cost-benefit analysis (World Bank, 2001).

<sup>41</sup>I have calculated this cost-benefit with different discount rates to provide a sense of the role that it plays in calculating the net present value (NPV). Re-calculating the upper bound NPV estimate with a 10% discount rate, the NPV equals \$176.1 million and with a 8% discount rate, the NPV equals \$215.0 million.

## 8 Conclusion

This paper investigates how individuals re-allocate time from home production to market work following the construction of drinking water infrastructure. Given that processes of development often are associated with changes in household time allocation, it is important to understand how people re-allocate time saved. Using differences in the timing across villages, I identify the impacts of shared water infrastructure on household distance to water sources, individual time use, and agricultural production. Access to drinking water infrastructure results in increases in time allocated to leisure and market work, specifically work on the household farm. Time reallocation occurs for both males and females, a logical result given they both contribute to water collection.

The greater amount of time spent working on the small farms appears to translate into greater production of cereals, which are grown solely on the small farms. Significant increases in production of maize and barley indicate that the time constraint during peak sowing and harvesting months was relaxed as a result of the water infrastructure. Calculations of returns to the additional farm labor are approximately equal to half the hourly skilled farm wage.

To date, much of the empirical work estimating the impacts of drinking water provision has been related to health impacts. This study shows that even in the absence of obvious health impacts, water infrastructure may have a substantial NPV due to the reallocation of time from home production to market work. Although the reallocation of time savings from water collection to market work is a frequently-mentioned benefit of water infrastructure, until now little rigorous evidence supported this actually occurring.

This paper is relevant to other contexts in which households are labor-constrained and therefore must make this trade-off between home production activities necessary for life and income-generating market work. Additionally, these results are applicable to locations that may not currently be labor-constrained, but where water scarcity is a concern. The IPCC has documented increasing frequency and intensity of droughts in certain areas of Africa and much of Asia, with climate change projections indicating increased future water stress in Africa and decreased freshwater availability in many parts of Asia (United Nations, 2010). In locations where water is becoming increasingly scarce, some households will face greater travel time to water sources and/or longer queues at their sources. In the face of climate change and increasing water scarcity, policy-makers ought to understand the time intensity of home production in the presence of poor quality or absent water infrastructure and how households deal with this time allocation trade-off.

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Table 1: Length of Time from Household to Water Source in Northern Kyrgyzstan

Region	Average number of minutes	Number of households
Issyk Kul	27.42	215
Naryn	25.36	288
Talas	24.04	273
All North	25.68	776

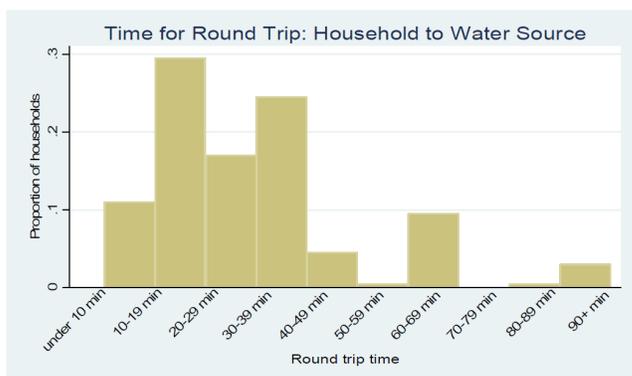


Table 2: Village Baseline Characteristics

	(1)	(2)	(3)	(4)
	All Villages	No water construction villages	Water construction villages	Difference (3-2)
Population	1676	1849	1551	-298.2 (200.4)
Number of households	337.9	390.1	299.7	-90.42 (47.93)*
Household size	5.2	5.077	5.2	0.156 (0.073)**
Proportion of (working age) population not employed	0.278	0.253	0.297	0.044 (0.033)
<i>Proportion of HHs receiving income from:</i>				
Formal employment	0.370	0.371	0.370	-0.001 (0.010)
Government pensions	0.099	0.101	0.098	-0.003 (0.004)
Government assistance	0.009	0.009	0.009	0.000 (0.002)
Self-employment	0.515	0.509	0.519	0.010 (0.007)
Proportion of adults: atleast secondary education	0.561	0.562	0.561	-0.001 (0.011)
Observations (# of villages)	245	79	137	

Notes: Calculated using 1999 Census data from the Kyrgyz National Statistics Committee, which provides data on all villages (rather than the limited random sampling from the KHS). The sample for these calculations is limited to those villages (38 in total) that were eligible for the water infrastructure program. The columns marked "No water construction" are calculated for those villages that were eligible but did not receive the water infrastructure during the program. The

Table 3: Summary Statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		No water construction	Water construction	Difference (3-2)	No water construction	Water construction	Difference (6-5)	Difference in Difference
<b>Panel A: Household characteristics</b>								
Main drinking water source is								
Shared piped water	0.478	0.434	0.4086	-0.025 (0.130)	0.570	0.5137	-0.0563 (0.143)	-0.031 (0.100)
Unprotected water	0.219	0.0686	0.3196	0.251 (0.112)**	0.0640	0.328	0.264 (0.118)**	0.013 (0.060)
Water <200m from HH	0.717	0.753	0.689	-0.064 (0.109)	0.739	0.7148	-0.0242 (0.113)	0.040 (0.134)
<b>Panel B: Farm characteristics</b>								
Number of land plots	1.800	1.623	1.83	0.207 (0.145)	1.789	1.899	0.110 (0.141)	-0.097 (0.074)
Total size of plots (sq. meters)	21942	12655	23837	11182 (4475)**	21476	26718	5242 (3590)	-5940 (3590)
Proportion of land cultivated	0.946	0.983	0.945	-0.0380 (0.025)	0.973	0.9043	-0.0687 (0.0315)**	-0.031 (0.040)
Proportion of land privately owned	0.978	0.992	0.9658	-0.026 (0.016)	0.996	0.9695	-0.0265 (0.0117)**	-0.000 (0.015)
Proportion of land irrigated	0.963	0.989	0.9659	-0.023 (0.016)	0.973	0.9359	-0.0371 (0.0307)	-0.014 (0.036)
Total farm-related expenditures (Kyrgyz soms)	2929	2677	2979.2	302.2 (1060)	2752	3170.9	418.9 (937.1)	116.7 (581.1)
Average annual household harvest (kg) of								
Cereals	1699	1109	2295	1186 (899.0)	1702	1468.1	-233.9 (628.5)	-1419 (932.8)
Vegetables	3367	4761	2894	-1867 (1807)	4223	2503	-1720 (1243)	146.5 (984.5)
Fruits	238.9	342.3	58.4	-283.9 (140.3)*	350.9	274.23	-76.67 (214.6)	207.2 (245.8)
Nuts	0.628	0.222	0.00	-0.222 (0.198)	1.589	0.778	-0.811 (1.167)	-0.589 (1.223)
Fodder	56.26	21.09	34.58	13.49 (12.07)	148.9	33.8	-115.1 (95.32)	-128.6 (96.55)
Observations (# of households)	858	175	247		175	261		
Number of villages	38	15	22		15	23		

Notes: Results are for difference-in-differences regressions using household survey data collected via the Kyrgyz Integrated HH Survey for baseline years (2003 and 2004). The sample for these calculations is limited to those villages (38 in total) that were eligible for the water infrastructure program. The 2004 (and later iterations as well) KHS sample included more villages than in the 2003 KHS. For this reason 2003 has 37 villages, whereas 2004 has 38 villages. The columns marked "No water construction" are calculated for those villages that were eligible but did not receive the water infrastructure during the program. The columns marked "Water construction" are calculated for those villages that were eligible and received the water infrastructure during the time of this program. Details on the village selection are described in the paper text. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 4: Household Water Access, Difference-in-Differences

Main drinking water source is:	(1)	(2)	(3)
	shared piped water	unprotected water	located <200m from HH
Water system	0.264 (0.110)**	-0.299 (0.0943)***	0.187 (0.0812)**
District-year Fixed Effects	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Mean baseline water access	0.483	0.231	0.794
Number of villages	38	38	38
Household observations	3,235	3,235	3,235
R-squared	0.544	0.560	0.303

Notes: Results are for difference-in-differences regressions using the household survey data collected annually via the Kyrgyz Integrated Household Survey. Data include all years between 2003 and 2010. Observations are at the household level. Sample is limited to those villages (38 in total) that were eligible to receive te water infrastructure through the program. Baseline means are calculated for 2003 and 2004. All regressions include controls for household characteristics (the number of rooms in the home and the total reported household income). Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 5: Aggregated Time Use of Household Members, Difference-in-Differences

	(1)	(2)	(3)
	Home Production	Market Work	Leisure
<i>For males and females, the number of minutes spent...</i>			
Water system	-169.7 (47.43)***	89.90 (33.64)**	79.79 (37.50)**
Mean (# minutes per day)	983.50	135.90	320.60
Observations	2,184	2,184	2,184
R-squared	0.403	0.314	0.304
Number of villages	38	38	38

Notes: Time use data were collected for household members 12 years and older via the Kyrgyz Integrated Household Survey in 2005 and 2010. Results are for difference-in-differences regressions. Observations are at the individual level. Sample is limited to those villages (38 in total) that were eligible to receive the water infrastructure through the program. Time use is measured in number of minutes per twenty-four hour period (totalling 1440 minutes). All regressions include the following controls: (1) season dummies, (2) day of week dummies, (3) respondent age and gender, (3) size of respondent's household, (4) district-year fixed effects, and (5) village fixed effects. Means are calculated for 2005. For a description of the time use categories, see Appendix. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 6: Detailed Time Use of Household Members, Difference-in-Differences

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Types of Market Work		Types of Home Production				
Work on HH farm	Regular paid work	Other work	Transport to/from work	Work in home garden	Caring for children	Self care (excluding sleep)	Leisure
<b>Panel A: For males, the number of minutes spent...</b>							
Water system	116.4 (37.31)***	-2.886 (10.26)	-14.46 (25.98)	3.834 (2.746)	-23.85 (40.50)	-14.59 (9.072)	-50.81 (9.653)***
Mean (# of minutes)	218.95	21.52	32.55	13.58	97.11	8.17	153.84
Household observations	1,090	1,090	1,090	1,090	1,090	1,090	1,090
R-squared	0.518	0.180	0.201	0.253	0.308	0.250	0.352
<b>Panel B: For females, the number of minutes spent...</b>							
Water system	96.41 (18.10)***	-20.73 (10.00)**	-24.76 (11.39)**	7.806 (3.886)*	-26.53 (30.14)	-29.61 (26.22)	-86.29 (16.65)***
Mean (# of minutes)	59.94	32.56	38.75	6.36	72.16	51.34	165.31
Household observations	1,094	1,094	1,094	1,094	1,094	1,094	1,094
R-squared	0.328	0.127	0.128	0.251	0.327	0.166	0.531
Number of villages	38	38	38	38	38	38	38

Notes: Results are for difference-in-differences regressions. Time use data were collected for household members 12 years and older via the Kyrgyz Integrated Household Survey in 2005 and 2010. Observations are at the individual level. Sample is limited to those villages (38 in total) that were eligible to receive te water infrastructure through the program. Time use is measured in number of minutes per twenty-four hour period (totalling 1440 minutes). All regressions include the following controls: (1) season dummies, (2) day of week dummies, (3) respondent age and gender, (3) size of respondent's household, (4) district-year fixed effects, and (5) village fixed effects. Means are calculated for 2005. For a description of the time use categories, see Appendix. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 7: Village-level Health Outcomes, Difference-in-Differences

	(1)	(2)	(3)	(4)
	Acute intestinal infection		Hepatitis A	
<i>Panel A: Village-level incidence in children 14 years old and younger (per 100,000 children)</i>				
Water system	-105.6 (50.96)**	-140.4 (55.09)**	-19.79 (46.96)	-12.33 (44.28)
Mean baseline incidence		305.9		201.7
R-squared	0.455	0.341	0.370	0.263
<i>Panel B: Village-level incidence in adults 15 years and older (per 100,000 adults)</i>				
Water system	-6.424 (19.47)	-6.065 (22.43)	12.81 (14.23)	1.782 (13.77)
Mean baseline incidence		106.9		51.71
R-squared	0.526	0.398	0.312	0.236
Dist-year fixed effects	Yes	No	Yes	No
Year fixed effects	No	Yes	No	Yes
Observations (# of village observations)	2150	2150	2150	2150
Number of villages	215	215	215	215

Notes: Results are for difference-in-differences calculations using village-level health data collected by the Kyrgyz Ministry of Health for the year between 2000 and 2009. Their definition of acute intestinal infections includes dysentery, giardia, enterobaecees, acariasis, and acute viral hepatitis. All regressions include village fixed effects. Baseline means are calculated for 2000-2004. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.



Table 9: Returns to Labor

	(1) Cereals harvested (kg)	(2) Cereals and fodder harvested (kg)
Total farm work (minutes/24-hour period)	3.563 (0.959)***	3.438 (0.957)***
Log total farm work		
First-stage		
Coefficient on "water system" variable	337.62***	337.62***
<i>F</i> statistic	19.22	19.22
Household observations	635	635
Number of villages	38	38
R-squared	0.579	0.581

Notes: Data are collected via the KIHS. Years are limited to 2005 and 2010, as those were the years in which time use data were collected. Sample is limited to villages that were eligible to receive te water infrastructure through the program (38 in total). Observations are at the household level. Cereals and fodder harvested are measured in kilograms. Total farm work is the total number of minutes that all working-age household members spent working on the farm in one 24-hour time period. All specifications include village fixed effects, district-year fixed effects, as well as fixed effects for day of the week in which the data were collected. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

# Appendix

Appendices 1a and 1b: Common characteristics of home gardens and small farms (2003)

	<b>Home gardens</b>	<b>Small farms</b>
<b>Typical location</b>	Adjacent to house	Outskirts of village
<b>Average size</b>	.29 acres	4.7 acres
<b>Labor provided by</b>	Both males and females	More males than females
<b>Typical crops grown</b>	Most fruits and nuts, some vegetables	All cereals, all fodder/hays, some vegetables
<b>Income potential</b>	83% of home gardens cultivated solely for household consumption	30% of farms cultivated solely for household consumption 67% of farms cultivated for both family consumption and sales
<b>Irrigation</b>	Typically households carry water from nearest source, only 11% of land is irrigated by canals	35% of land is irrigated by canals and 59% is irrigated by diverted river water

Home gardens



Small farms



Source: Google earth

Appendix 1c: Alternative Farm Inputs, Difference-in-Differences

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Farm expenditures (KGS)	Cultivated land (hectares)	Irrigated area (hectares)	Log farm expenditures	Log cultivated land	Log irrigated area
Water system	-388.2 (626.1)	870.8 (2,803)	760.1 (2,874)	0.110 (0.219)	0.0773 (0.179)	0.0891 (0.176)
Mean baseline	3216.6	22754.1	23195.6	3216.6	22754.1	23195.6
Household observations	3,221	3,208	3,208	2,464	3,189	3,195
Number of villages	42	42	42	42	42	42
R-squared	0.346	0.161	0.167	0.544	0.343	0.345

Notes: Results are for difference-in-differences regressions using the household survey data collected via the Kyrgyz Integrated HH Survey between 2003 and 20010. Sample is restricted to those villages that applied to receive a water supply system. Baseline means are calculated for 2003-2004. Farm expenditures are in Kyrgyz soms (KGS); during this period of time the average exchange was approximately 41.32 KGS=1 USD. "Water system" is an indicator of whether the village received the water infrastructure. All columns include controls for (1) Controls for land characteristics; (2) number of people and children 14 and younger in a household; (3) district-year fixed effects; and (4) village fixed effects. Controls for land characteristics include: total plot size, proportion of land irrigated, number of land plots total, proportion of land that is privately owned, proportion of land that is cultivated, and total farm-related expenditures. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

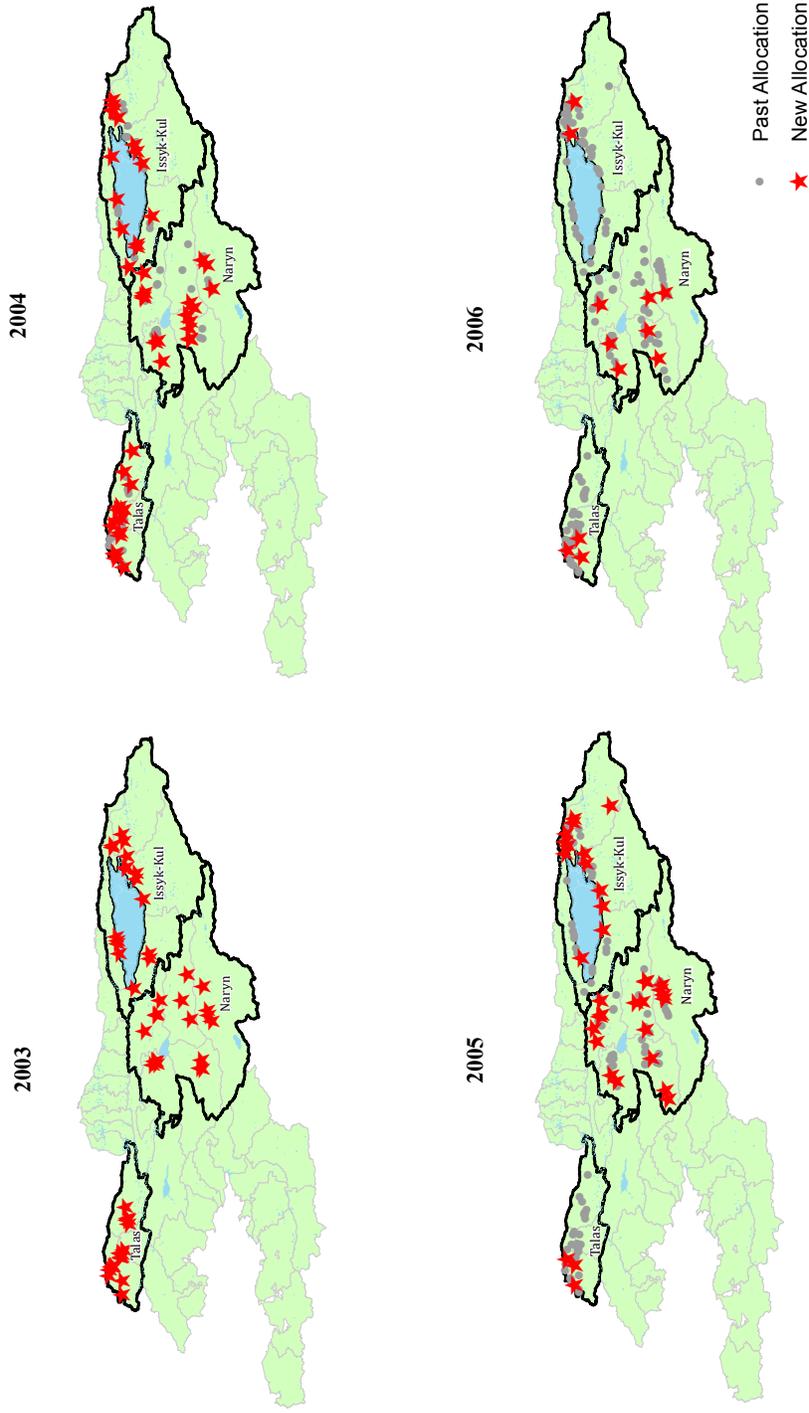
Appendix 2: Percent distribution of households according to the person collecting water used in the household (2006)

<b>Region</b>	<b>Adult women</b>	<b>Girls &lt; age 15</b>	<b>Adult men</b>	<b>Boys &lt; age 15</b>	<b>Total adult</b>
Issyk Kul	28.2	6.8	47.4	13.4	75.6
Naryn	27.5	8.5	46.2	13.2	73.7
Talas	37.9	5.3	47	8.2	84.9

Source: UNICEF Multiple Indicator Cluster Survey, 2006.

Appendix 3: Village selection over time

Water Infrastructure Allocation to Villages



Kyrgyzstan Map with District and Province Boundaries:  
United Nations Office for the Coordination of Humanitarian Affairs  
(January 22, 2013)

Village selection process description:

An effort was made to select villages for the intervention in a transparent and fair manner to receive the water supply systems. All villages in the three provinces, 322 in total, were informed of the upcoming large-scale project and the process of applying to participate, should their village require an improved water supply system. If interested, village heads were required to send a letter of intent on behalf of their constituents. This resulted in 255 eligible villages identified. Between 2003 and 2006, approximately 200 rural villages in the northern 3 provinces of Kyrgyzstan were selected to receive an improved water supply system, in the form of communal standpipes, through this effort.

Each eligible village was scored based on five factors:

1. Need for water: determined through a participatory community appraisal and through the observations of the project engineers;<sup>42</sup>
2. Poverty levels: determined based on numbers of people living in poverty as calculated by the local government;
3. Economic and technical feasibility: based on the project engineers calculations of the cost per person, which was typically higher if the water source was located far enough away to necessitate long distances of water pipes; and
4. Community participation: based on expressions of support from community groups and their participation in previous projects.

Efforts were taken to try to ensure that the scores were not manipulated for political reasons; final scores were an average of scores provided by a panel of representatives from government agencies and international organizations. Scores were used to determine when a village received a water supply system through this program. Selection occurred annually from 2003 to 2006, with some portion of villages selected in each of those years. Due to an effort to ensure that all districts in the three northern provinces would be represented, albeit not equally, scoring was stratified by district.

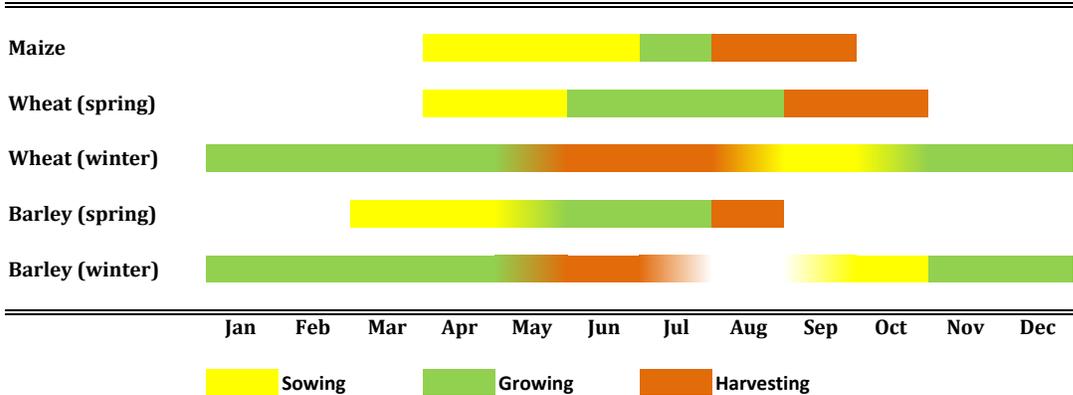
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<sup>42</sup>This was allocated twice the weight of the other score components.

#### Appendix 4: Major Categories of Time Use

<b>Variables</b>	<b>Description</b>
Total work	Includes formal work, informal work, farm work, and work in home gardens.
Formal work	Includes work that is paid a salary.
Informal work	Includes work that is entrepreneurial, intermediary, trade, or individual working activity.
Work in farms	Includes work in farms for crops and livestock.
Work in home gardens	Includes work in home gardens for crops and livestock.
Transportation to/from work	Time spent commuting to work.
Housework	Includes time spent buying groceries and non-food items, cooking, dishes, laundry, sewing, cleaning, taking care of elderly family members, and other types of domestic labor.
Education	Includes studies, training, and self-education.
Free time	Includes various leisure activities, such as time spent going to the cinema or theater, watching TV, listening to the radio, walking with friends, sports and exercise, hobbies, religious activities, and doing nothing.
Self care	Includes time spent bathing, looking after oneself, eating, going to hospitals and bath houses, and sleeping.
Care of children	Includes time spent feeding, washing, bathing, and attending to children.
Helping others	Includes helping relatives and acquaintances.

Appendix 5: Timing of main cereal crops: sowing and harvesting



Source: Created based on information from FAO (2009) and FAO GIEWS (2011).