Water and Human Capital

Impacts across the lifecycle

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WATER AND HUMAN CAPITAL

IMPACTS ACROSS THE LIFE CYCLE

CONCEPTION TO BIRTH

Impacts begin long before a child is born

- Water-borne and sanitation related impacts
- Food deficits due to rainfall deficiency and variability

41% drop in neonatal fatality due to handwashing interventions

INFANCY TO CHILDHOOD

The early years are a critical time for determining whether a child will grow up stunted

- Water-borne and sanitation related impacts
- Impacts due to rainfall deficiency and variability

Women in Africa born during **rainfall deficiencies** are more likely to **grow up stunted**

CHILDHOOD AND ADOLESCENCE

Adolescents accumulate human capital through education

- Water-borne and sanitation related impacts
- Water collection time

25% of girls in India skip school during menstruation due to **lack of sanitation**

Water treatment interventions in rural China increased schooling by **1.1 years**

ADULTHOOD

Premature mortality and morbidity

- Water-borne and sanitation related impacts
- Extreme rainfall events

In 2016, **diarrheal diseases** were the **second leading cause of death** in low-income countries.

1. Water and Human Capital Formation

At the FY19 Annual Meetings in Bali, the World Bank released the Human Capital Project and the associated Human Capital Index (HCI), to much acclaim. The HCI is both an indicator of current development success, as well as a metric of a country's foregone development potential. It combines five measures of human capital into a single index to quantify the contribution that health and education have on the productivity of the next generation of workers. These five indicators are:

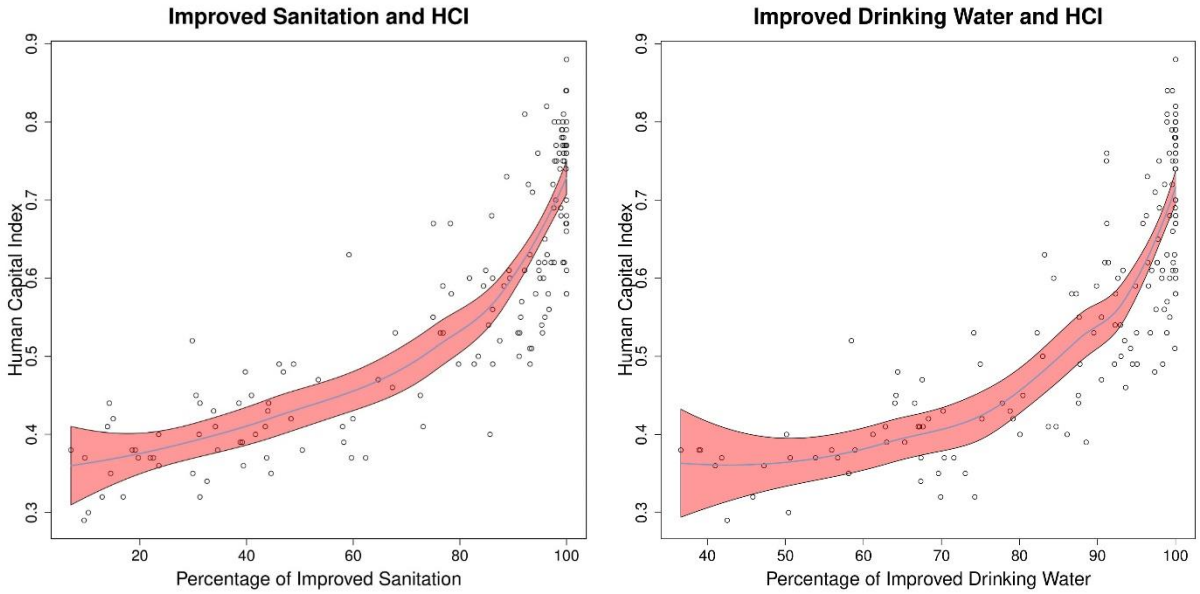
- Probability of survival to age 5
- Expected years of school
- Harmonized test scores
- Fraction of children under 5 not stunted
- Fraction of 15-year olds surviving to age 60

The data are collected separately for both males and females and countries are ranked by each component, as well as for the overall index. This allows countries to compare themselves to peers and chart their progress over time. Importantly, the HCI is a way to kick start conversations on ways to invest in citizens' futures, identify where needs are most urgent, and where proper attention can yield the biggest payoffs.

The indicators which comprise the index are all measures of health and education. And while none of these indicators explicitly mention water, water underlies and impacts them all.

It is therefore no surprise, as Figure 1 shows, that there is a conspicuous link between access to improved water supply and sanitation and HCI. While these graphs do not imply a causal relationship, they illustrate and summarize the effects that these interventions have on human development outcomes.

Figure 1: The Relationship Between the Human Capital Index and the Percentage of Improved Sanitation (left) and Improved Water (right) Coverage



Notes: Human Capital Index (World Bank 2018); Improved sanitation and improved drinking water (JMP 2015). R square values for linear regression models are: 0.6898 (sanitation) and 0.6201 (water)

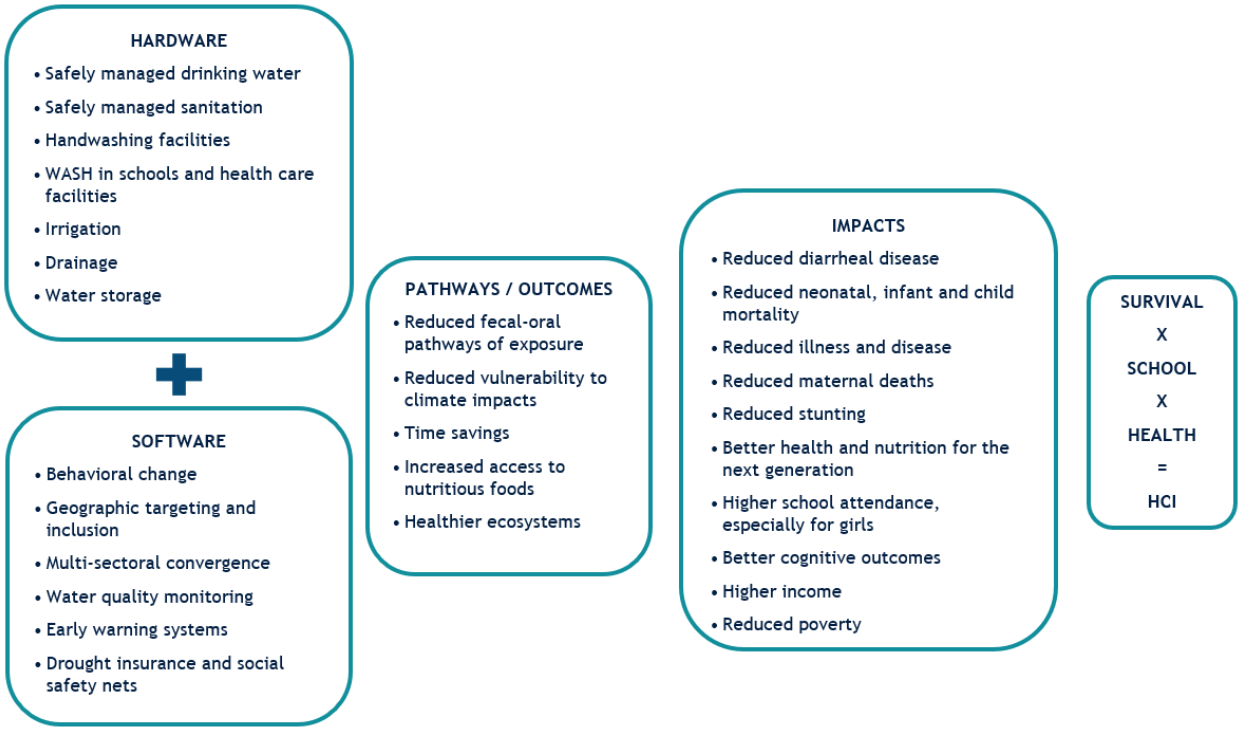
Source: Authors' calculations.

This brief note describes the frontier of scientific knowledge on the linkages between the water sector and human capital accumulation, and by consequence, the Human Capital Index. To do so, it takes a life-cycle approach, walking through the different stages of human growth, and how the water sector plays a critical role at each of these stages.

1.1 Linkages between Water and Human Capital

There are numerous pathways through which the water sector can impact human capital accumulation: access to improved water supplies, water quality, sanitation and hygiene; water for irrigation; and better management of water resources to protect against rainfall deficiency and variability, including extreme water-related climate events like floods and droughts (Figure 2). These sub-sectors are all critical for determining the total human capital an individual accumulates throughout their lives.

Figure 2: Theory of Change



While deficiencies in each of these areas can hamper human capital accumulation, the timing of when these occur during a person's life is crucial. Because human growth and development occurs non-linearly, a 'shock' or deprivation experienced by a young child may have devastating short- and long-term impacts, while the same deprivation experienced by an adult could be less harmful. This note therefore splits the life-cycle into four distinct epochs: conception to birth; infancy to early childhood; childhood and adolescence; and adulthood.

It is well established that deprivations and exposure to harmful conditions *in utero*, or in the very early years of life, have lasting consequences that can impede human development. For instance a host of waterborne illnesses may contribute to higher rates of infant mortality, undernutrition, stunting, anemia, and inflammation – conditions which impair cognitive functioning and physical development in children.[1] As the child moves through adolescence these impacts cascade beyond health – showing up through lower rates of school attendance and poor academic performance. In adulthood, this eventually translates into lower human capital, productivity and wages.[2] If there is further exposure to poor water quality and unhygienic sanitary conditions in adulthood, the burden of morbidity and mortality rises above baseline levels. A significant body of literature has attempted to quantify the economic costs of these impacts

typically in terms of productivity and labor market outcomes such as the wage penalty. There is also a less extensive, though convincing, body of evidence that documents water related extreme climate events on children who may end up stunted, less educated, and less wealthy.[3] Each sub-section explores the current evidence of the critical role that the water sector plays for human capital accumulation in each period.

Conception to birth

The importance of the water sector for human capital accumulation begins long before a child is even born. Developing fetuses can be especially susceptible to water-borne and sanitation related infections or diseases experienced by their mother.

Sanitation and hygiene. Indeed, women exposed to poor sanitary environments were found to be more than twice as likely to experience a preterm birth or other adverse pregnancy outcomes in rural India, [4] and 1.71 times as likely to have a stillbirth in Nepal,[5] even when controlling for confounding factors like poverty, religion, education, and caste of the parent.

Simple hygiene interventions, such as handwashing, can lead to dramatic improvements in birth outcomes. Neonatal fatality also declines dramatically, by some 41 percent, when mothers and birth attendants practice handwashing with soap.[6] About 11% of maternal deaths worldwide are caused by sepsis, an infection that is directly linked to unhygienic conditions during labor and childbirth.[7] Unsurprisingly, these deaths occur nearly entirely in the developing world, and are most common in Sub-Saharan Africa and South Asia, where access to sanitation and hygiene lag the rest of the world.

Water quality. An often less visible, but equally deadly, killer is water pollution. Water pollution can come in many forms, including fecal contamination from untreated wastewater, industrial and chemical pollutants, nutrient pollution such as nitrogen and phosphorus from agricultural runoff, and geogenic pollution from naturally occurring chemicals. The number of chemical, bacterial, and other water quality parameters that are harmful to human health range in the thousands. Many of these are invisible to the senses but could be lethal; while others may require exposure over many years to lead to an adverse outcome; still others can have severe contemporaneous effects.

Agricultural pollution, particularly nitrogen, phosphorus, and their derivatives, are linked to significant increases in infant and neo-natal mortality, particularly if exposure occurs during the month of conception. The strongest causal evidence is from India where the Green Revolution offers a natural experiment of how consistent increases in nitrogen use have impacted infant deaths.[8] Similarly, increased

levels of biological oxygen demand (BOD) in water, which is often caused by waste from industries like paper and pulp processing, printing, and textile and fabric, can also have adverse effects on human health. When the Indian Water Act and Environmental (Protection) Act limited the amount of (BOD) pollution from the tanning industry, neonatal mortality dropped by 3 percent.[9] Similarly, piped water interventions in Brazil have been shown to significantly reduce infant mortality, particularly in poor areas.[10]

In sum, there is a wide body of evidence from across the globe, which quantifies the lethal consequences of early life exposure to a wide range of biological and chemical waterborne pollutants.

Infancy to Early Childhood

Early childhood is a critical time for determining whether a child will grow up stunted. When a child is stunted, often the effects do not just reflect shortness in height. Stunting can have severe consequences on cognitive development, overall health, and even socio-economic conditions that carry into adulthood.[11] While stunting is not a direct indicator of health, it is a proxy for the overall environment during the prenatal, infant, and early childhood years. Stunting is generally caused by lack of nutrition while *in utero*, during infancy, or in early childhood which prevents the body from developing to its potential. This could be the result of consuming too few macro- and micro-nutrients, or by being exposed to an adverse disease environment, especially diarrheal diseases, which prevent the body from absorbing nutrients that are consumed. Children exposed to unsanitary environments frequently develop a condition known as *environmental enteric dysfunction* (EED), which is characterized by inflammation and physical deformation of the small intestine.[12] EED inhibits the absorption and retention of essential nutrients, which researchers hypothesize is a major cause of stunting.[13] In each of these cases, access to water sector services plays an important role in ensuring adequate nutrition.

Sanitation and water quality. Even when there is access to plentiful food and nutrition, waterborne diseases are known to prevent the body from absorbing the requisite nutrients. As a result, poor sanitation and water quality and the resulting diarrheal diseases are the second and third leading risk factors for stunting worldwide, with a combined 13 million cases in 137 developing countries.[14] WASH interventions which reduce community levels of open defecation,[15] or improve drinking water quality,[16] have been shown to have significant effects on increasing child height-for-age and reducing under-5 stunting. There is further evidence that better sanitary conditions in early childhood helps to prevent anemia, which is caused in part by poor absorption of essential nutrients and is directly related to human capital formation. Evidence suggests that interventions have the largest measurable impact where local population densities

are highest. This is simply a consequence of the larger number of impacted people and the greater concentration of contaminants in areas where people live more closely together.[17]

Irrigation. Irrigation interventions play a critical role in ensuring individuals have more stable access to the nutrition they need to reach their genetic potential. Irrigation enables more cropping seasons, including during dry periods[18] and reduces the risks of rainfed production.[19] Irrigation increases income from improved crop productivity[20] and broadens the range of crops that farmers are able to cultivate—particularly those with higher water requirements such as fruits and vegetables, which have higher nutritional and market value.[21] These benefits translate directly to the availability of and access to nutritious foods for home consumption, as well as through market purchases.[22]

Extreme events and rainfall variability: Finally, extreme water-related climate events such as droughts and floods deliver multiple misfortunes—destroying assets and reducing incomes while at the same time deteriorating the disease environment. A child that experiences such extreme events has a significantly increased probability of growing up stunted, especially when experienced before the age of 3.[23] And where incomes are fragile and dependent on agriculture, even modest increases in rainfall during early-life can increase incomes and improve the disease environment, enough to show long term gains in height- and weight-for-age.[24]

Childhood and Adolescence

Childhood and adolescent years are critical for human capital accumulation through education. According to the human capital index, every quality-adjusted year of education has an 8 percent payoff, for every year of adulthood. Thus, a single additional year of education, or a modest increase in its quality, can pay very large dividends that compound each year.

The water sector can impact completed years of schooling in several ways. When children are healthier, well-fed, and have access to safe water and quality facilities, they are more likely to attend school.

Sanitation and hygiene. Indeed, improved access to sanitation facilities in schools has been linked to increased enrollment in primary schools in India[25] and a higher rate of school completion in Brazil.[26] In India, a meta-analysis of 138 studies found that 25 percent of girls did not attend school during menstruation because of lack of adequate toilets in the school.[27] A meta-analysis of school-based WASH interventions found that overall these resulted in a 69 percent reduction in school absenteeism and were similarly associated with lower dropout rates.[28]

Water availability. A water source closer to home is especially beneficial for women and children, who shoulder the largest burden of water collection.[29] In Ghana, halving the time it takes to fetch water increases the share of girls in school by about 7 percentage points,[30] while in India access to a water source close to home is associated with improved female literacy.[31]

Water quality. Likewise, access to treated, piped water in the home has been causally linked to higher completed school years in 39 countries in Sub-Saharan Africa,[32] China,[33] and even early-1900s era United States.[34] Emerging (unpublished) evidence also suggests that improved performance at school is causally linked to water supplies with lower levels of salinity.

The timing of interventions is found to be pivotal. Impacts of clean water and sanitation in the early years have a more powerful impact on educational outcomes, multiplying the benefits of better schooling. Thus, in urban Pakistan, early childhood exposure to handwashing promotion led to improved scores on developmental milestones. The magnitude of improvement was similar to that found for at-risk children enrolled in publicly-funded preschools in the United States – but achieved at a much lower cost.[35] Similarly, Indian children who experienced better sanitary conditions in their first year of life had improved cognitive achievement scores later in life, including better ability to recognize simple letters and numbers by the age of six.[36] In Mexico, a major water reform program, *Programa de Agua Limpia*, disinfected previously untreated water supplies. This led to significantly improved academic achievement in treated areas for those who were infants during the time of treatment.[37] Cognitive abilities have also been shown to be linked to early-life rainfall and floods. Children in Mexico who experienced ENSO-related floods have 11-21 percent lower test scores in language development, working-memory, and visual-spatial thinking abilities than the unexposed.[38]

Adulthood

By the time an individual enters adulthood, much of the human capital index is already determined. However, there remain two ways in which the water sector's importance manifests itself through the HCI in adulthood – impacts on morbidity and premature mortality. In addition, there are the legacy impacts of deprivations encountered in the earlier stages of life.

Contemporaneous health impacts: The consequences of poor sanitation and water quality for morbidity and mortality are well known. In 2016, diarrheal diseases were the second leading cause of death in low-income countries, killing nearly 60 out of every 100,000 people.[39] Poor WASH is implicated as the cause of 58 percent of these deaths.[40] Cholera, an acute diarrheal disease linked to contaminated water that

can kill within hours if untreated, infects up to 4 million people each year, killing an estimated 21,000-143,000 people.[41] Other diseases, like typhoid and measles increase precipitously in the developing world when domestic water supply outages occur.[42] In some individuals these diseases are fatal, and in many others their burden reduces labor productivity and wages. Where the burden is high, repeated illnesses for family members can trap households in a poverty cycle. WASH is also key for preventing opportunistic infections associated with HIV/AIDS, and in the quality of life of people living with the disease. Immuno-compromised individuals are more susceptible to and suffer greater effects from water- and sanitation-related diseases.[43]

Adult impacts from childhood deprivations: A developing fetus, infant, or young child is sensitive to a host of environmental factors which can impair development and play a significant role in shaping adult outcomes.[44] This has been shown over and over again in both the economics and medical literature and is often referred to as the *fetal origins hypothesis*.[45] The recent World Bank report, *Uncharted Waters*,[46] examined birth outcomes of over 100,000 women born in 19 sub-Saharan countries between 1953 and 1998. It found that women born during periods of below average rainfall grew up to be significantly shorter, less educated, and less wealthy. Dramatically, it also found that these impacts were transmitted over generations, with the children of these women more likely to suffer from an anthropometric failure—that is, being significantly below average size in terms of height for age, weight for age, or weight for height. Similar adult impacts of low early-life rainfall have been found in well-known studies, including impacts on height and wealth in Indonesia, [47] and increased adult disability rates in South Africa. [48] In all of these studies, the main transmission method is through impacts of rainfall on agriculture. When agricultural income is depressed, young children are less likely to receive the nutrition their developing bodies and minds require, as well as the investments in education that are important for their future, hamstringing their future success.

Likewise, access to water and sanitation during early-life can also pay large dividends down the road. In India, adults who were born in regions with worse disease environments earned significantly lower wages later in life.[49] As discussed in the prior section, the disease environment can impact how infants and children are able to absorb nutrients, impacting physical and cognitive development. The implications are that WASH investments can have positive externalities which ripple across time.

1.2 Conclusion

The Water GP has invested heavily in the analytical foundations that are directly related to human capital formation, and a large share of the portfolio is aligned towards investments that achieve greater impacts on the indicators underlying the HCI. The evidence laid out in the prior section shows that the water sector—inclusive of improved water supplies; access to improved sanitation and hygiene; improved water quality; water for irrigation; and protection against extreme water events—can have enormous impacts on human capital accumulation that have been documented across a range of circumstances and geographies. Some of these impacts are felt contemporaneously, such as when they lead to illness, missed school, or mortality, and some of them have much longer-term impacts on human development, cognition, and ultimately wages, wealth, and wellbeing. Given these links, it is not surprising that the HCI correlates so highly with water sector indicators. The next section provides a brief snapshot of water sector engagements designed to promote human capital development through WBG investments.

2. Examples of water investments in human capital

Since water impacts human capital through multiple pathways there is often a need to invest in cross-sectoral interventions. In fact, analysis conducted under the WASH Poverty Diagnostic Initiative shows that efforts to improve WASH, coordinated with other health interventions, can have effects greater than the sum of its parts. Children who have simultaneous access to adequate levels of two or more of the underlying determinants of nutritional status— food security, health care, child care practices, and access to water and sanitation, are less likely to be stunted than children who have access to only WASH or only health care. Indeed, WASH project components are frequently included in Health, Social Protection, Education, and Social Development operations, and WASH is a core intervention for Early Years[50] investments to reduce childhood stunting across 14 countries in 4 regions. Likewise, strong partnerships are maintained with other agencies and NGOs to leverage their comparative advantages in areas such as behavior change and community engagements.

Below, is a snapshot of a select number of projects that illustrate the range of HCI sensitive water investments:

Ending Open Defecation in India through the Swachh Bharat (Clean India) Mission PforR (US$ 1.5 billion)

Globally, in 2015, about 900 million people defecate in the open, of which about 560 million reside in India. Changing centuries-old habits of defecating in the open is a complex undertaking. Recognizing the

magnitude of the challenge the Government of India has invested over $20 billion to end open defecation through the Swatch Bharat Mission. The aim is to simultaneously provide toilets and change behavior through a mass-movement that is supported by the institutions of the Government of India. While the level of success will vary across the country, emerging research suggests that the health benefits will be greatest in areas with the highest population densities and the more educated populations, such as the peri-urban areas (though many are still classified as rural in India).

Scaling-up Sustainable Sanitation Services in Egypt PforR (US$ 1.15 billion)

The Egypt Sustainable Rural Sanitation Services Program provides sanitation access to over 1.7 million people in the Nile Delta region of Egypt and is helping to formulate sector policy and strengthen institutions that will enable country-wide scale up of rural sanitation services. The Nile Delta is an agricultural powerhouse, but close to 1 in 5 people live in poverty. Most households rely on septic tanks or are connected to informal sewerage networks that discharge raw sewage directly into agricultural drains and water bodies. The wastewater is then used for irrigation of crops or flows downstream into the many canals and tributaries of the Nile River system – a major source of drinking water for the region. Through provision of household sewerage connections, the program has reduced pollution in the Nile River, and reduced the incidence of reported sewerage flooding events, leading to an overall cleaner and less disease-ridden environment. Building on this success the Asian Infrastructure Investment Bank is co-financing an additional phase of the program.

Nutrition-sensitive WASH and multi-sectoral convergence in Lao PDR (US$ 25 million – pipeline)

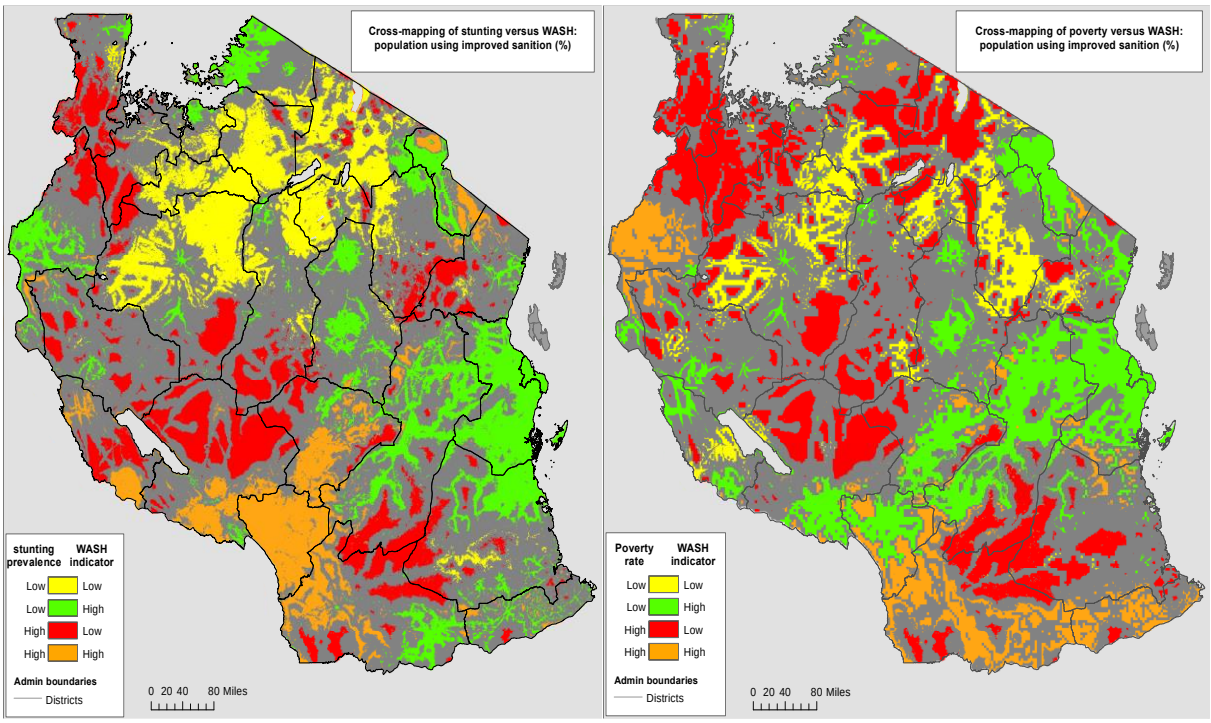
In Lao PDR, the Rural Water Supply and Sanitation Project will focus geographically in regions with ongoing and pipeline operations that address early child health and nutrition. This convergence helps to ensure that every child receives a package of interventions to address the causes of malnutrition. Households with pregnant women and children under two will receive social and behavioral change communication that focuses on child related exposure to harmful pathogens caused by unsafe WASH, complemented by improved sanitation and water supply infrastructure at the community level. The project supports sector wide water supply and sanitation monitoring framework that is harmonized with health sector monitoring system to track nutrition outcomes.

Improving targeting of WASH services to vulnerable populations in Tanzania (US$ 250 million)

In Tanzania, the WASH Poverty Diagnostic produced geospatial maps (Figure 3) to illustrate the cross section of sanitation, stunting and poverty levels. Areas marked in red highlight where access to improved

sanitation is low and stunting and/or poverty levels are high. These maps have been used to engage in a dialogue with the Tanzanian government and to identify target areas for WASH investments under the Rural Water Supply and Sanitation Program-for-Results operation. The PforR operation includes DLIs on community-wide coverage of sanitation and hygiene in schools and health facilities.

Figure 3: Cross-mapping of sanitation and stunting (left) and sanitation and poverty levels (right) in Tanzania



Source: Tanzania WASH Poverty Diagnostics.

Strengthening water security and resilience in Somalia (US$ 40 million – pipeline)

The Water for Agro-Pastoral Productivity and Resilience Project aims to tackle water for agro-pastoral productivity and resilience. Somalia is subject to repeated cycles of devastating droughts averaging one every four years and has experienced five major flood events in the years between 2006 and 2018, impacting hundreds of thousands of people. The last drought in 2016/17 led to 6.2 million Somalis requiring humanitarian assistance and close to 400,000 reported cases of acute child malnutrition. Livestock losses were estimated at US$2 billion, with people losing between 40 and 60 percent of their herd. The proposed project will provide access to multiple-use water resources (for human consumption, livestock and small-scale irrigation) in dry lands of Somalia. The small-scale water infrastructure will be designed to deliver on both improved human health outcomes and water for productive uses, including agricultural production and agroforestry services for landscape restoration.

Enhancing access to nutritious foods through farmer-led irrigation in West Bengal, India (US$ 155 million)

The West Bengal Accelerated Development of Minor Irrigation Project has reached 1,000 villages in rainfed, backward, drought prone, upland and tribal areas of West Bengal in India, and touched the lives of 1.2 million small and marginal farmers. The project provides access to water through construction of small irrigation structures, forming Water User Associations (WUAs) and building market linkages. This has led to improved access to water for domestic use in more than 600 villages, improved nutritional security and long-term ecological benefits. The availability of water has enabled the farmers to not only maximize production and income but has impacted communities through (i) increased access to high-nutrition content foods through cultivation of vegetables and fish; (ii) increased access to pulses and oilseed crops, enhancing food security; and (iii) increased income from farm production enabling farmers to invest in health and education for their children.

Increasing access to school sanitation and menstrual hygiene management in Ghana (US$ 155 million)

Recognizing the dire situation of sanitation in schools across the Greater Accra Metropolitan Area, US$ 24 million was committed under the Ghana Sanitation and Water Project for institutional sanitation facilities. This includes new and rehabilitated facilities in 200 schools reaching 150,000 students with safe, inclusive sanitation and hygiene training. The project also includes technical assistance to enhance facilities, training and oversight of menstrual hygiene management in schools.

3. Conclusions

A significant body of literature from across a variety of disciplines – epidemiological, public health and econometric - establishes that water plays a pivotal role in human development. There are multiple pathways through which water can impact human capital, related to the quality of water, the availability of water, behavioral factors that determine environmental and hygiene conditions, as well as through the damage caused by natural disasters. Physical and economic impacts are found to be highly age-sensitive. Deprivations in the earliest years of life not only have the most harmful health impacts, but also last longer and through crucial developmental stages of life, resulting in the greatest effects on human capital.

Recognizing the magnitude and pervasiveness of these challenges the Water GP has invested heavily in mitigating the risks generated by water to human development outcomes. The GP has also developed

practical tools to identify regions at greatest jeopardy from water-related risks. Going forward priority would be given to investing more heavily in areas with the highest risks to human development.

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