# WATER FOR EQUITABLE GROWTH

# II. Water for equitable growth

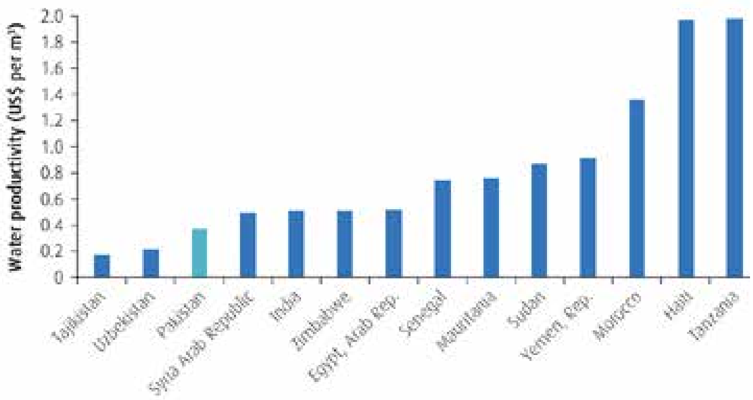
Contrary to popular perception, Pakistan is not running out of water—not just yet. The common refrain about Pakistan's water resources is that 'freshwater available *per capita*' is falling. But, as Annex B explains, the available freshwater has generally remained constant over the past decades. It is the population that has been rising—hence the fall in per capita freshwater available. **This chapter focuses on utilizing Pakistan's water resources in the agriculture sector to maximize economic growth.** In doing so, it outlines the real water-related challenges when it comes to the agriculture sector: serious water wastage, the state and management of the irrigation system, unrestrained withdrawals of groundwater, deteriorating water quality, and the coming impact of climate change on Pakistan's water resources.

## Water productivity is key

**For growth, water productivity (i.e., value created from each unit of water) is more important than water availability per capita.** Figure 10 shows that Pakistan is creating little value from its water even compared to a cohort of countries with comparable levels of water availability, low GDP per capita, high proportion of water used in agriculture, and importance of agriculture in GDP.

**Pakistan is among the few countries where more than 90 percent of the freshwater used by the country is devoted to agriculture.** To put this in perspective, on average, the countries of the world have the following distribution of the freshwater they use: 70 percent in agriculture, 20 percent in industry, and 10 percent in municipal uses (drinking water, public uses in towns, etc.). Pakistan's distribution is 93 percent in agriculture, 6 percent in industry, and 1 percent in municipal uses. The question of low water productivity is mostly a question of low productivity of water in agriculture.

Figure 10: Pakistan must create more value from its water




Countries with (i) >80% water used in agri, (ii) agri > 10% of GDP, (iii) water available per capita <3,000 m³ per annum, (iv) GDP per capita: US$800-4,000

*Source: World Bank 2019*

**Within agriculture, the five major field crops dominate water consumption.** Pakistan's farmers predominantly follow a two-harvest system for field crops: a summer cultivation season called '*kharif*' and a winter cultivation season called '*rabi*'. During *rabi* (winter), wheat is cultivated on more than 80 percent of Pakistan's farms while during *kharif* (summer), generally four major crops compete for acreage: cotton, sugarcane, rice, and corn (maize). During *rabi* (winter), wheat accounts for 79 percent of water consumption. During *kharif* (summer), cotton, sugarcane, rice, and corn consume 94 percent of water.

In the past two decades, the area under wheat, the main rabi (winter) crop, has risen by 11 percent to reach about 22 million acres in FY22. Of the crops cultivated during kharif (summer), a momentous expansion has been witnessed in rice (up 49 percent to 8.7 million acres), maize (up 75 percent to 4 million acres), and sugarcane (up 31 percent to 3.1 million acres). These enormous increases have been at the expense of the area under cotton (down 34 percent to 4.8 million acres). While some agro-climatic zones are more suited to some of these crops than others, over the past couple of decades, multiple failures have led to a sub-optimal distribution of crops by geographic area. But this depends on farmers' crop choices.

**Like any entrepreneur, the Pakistani farmer makes business choices based not only on profitability but also the risk calculus.** Figure 11 presents the value of water from the policy point of view compared to the farmer's business point of view (figure 12). The policy priority is that the highest value is generated from each drop of freshwater used in Pakistan. Figure 12 shows that a farmer can earn more per acre by growing sugarcane, but because of a higher water requirement, the productivity is lower than cotton.

From the farmer's business point of view, the value generated per acre is the priority. On this count, the opposite result appears for sugarcane as it emerges the most preferable while rice paddy (averaged between Basmati, IRRI, and hybrid varieties) emerges at the bottom. The clear winner, though, is horticulture which generates many times more value per drop even with conventional irrigation—and more value per drop by an order of magnitude with high efficiency irrigation system such as drip irrigation.

Figure 11: Policy priority: Fruits and veg are highest

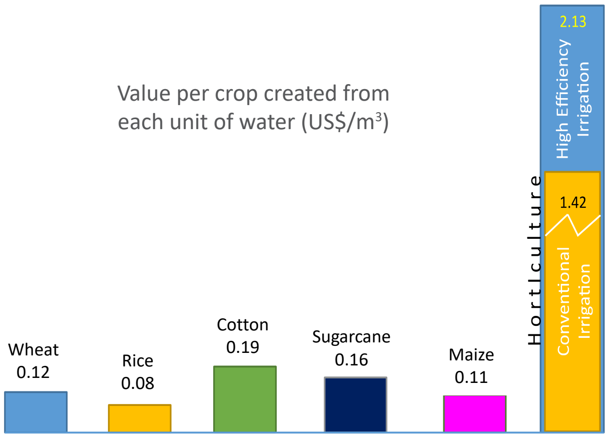
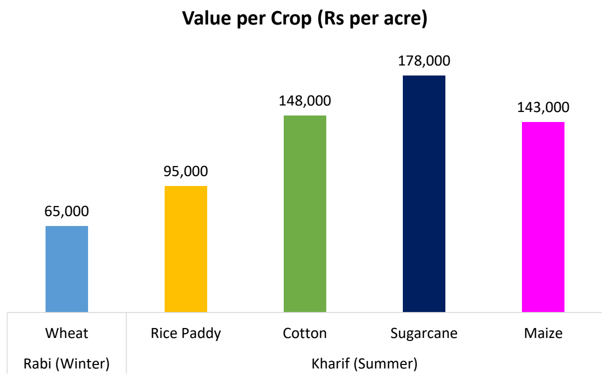



Figure 12: Farmer preference: Sugarcane is highest




*Source: FAO 2020*

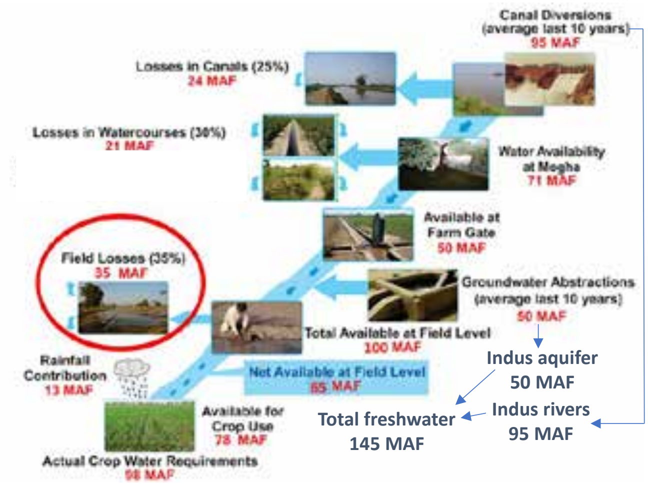
**Farmers' views on profitability and risk associated with each crop are shifting them towards crops that consume more water per unit of farmland (e.g., sugarcane) while the policy priority of 'more value per drop' favors cotton.** This situation illustrates the classic challenge of economic policy: to incentivize business decisions to align with national policy priorities.

In such situations, the obvious measure of economic policy is to increase the price of water in a way that the farmer's profitability is impacted in favor of cotton and maize in areas where they can replace sugarcane. But farmers' crop choices are unlikely to change in this way if other major risk factors are not addressed. For example, the reduction in the area under cotton in favor of other crops, particularly in the cotton heartland in southern Punjab, is a critical issue for Pakistan. Figure 11 suggests that, from a policy point of view, farmers should be incentivized to shift from sugarcane to cotton. But farmers have seen serious uncertainties associated with the cotton crop, particularly, the vulnerability to pink bollworm in the absence of modern seed, untimely and excessive rains with unsuitable drainage on farms, etc. This has rendered the cotton crop financially unviable for many farmers.

## Pakistan's key water-related challenge is the wastage of water

While available freshwater resources have remained stable (see Annex B), Pakistan's water consumption has remained constant in proportion with withdrawals showing little improvement in water use efficiency. To reduce the amount of water withdrawn for agriculture, improvements to the productivity of water must be addressed. Water productivity is basically the amount of GDP created per drop of water. Pakistan's current water productivity is the eighth lowest in the world at $1.38 per cubic meter of water withdrawn from the Indus River Basin and the Indus aquifer (see Annex B). The total water withdrawals are the fifth highest in the world (World Bank, 2019).

Figure 13: Every drop counts: water loss at each stage




The main source of low productivity stems from inefficiencies within the delivery system of water from the Indus Basin Irrigation System to the farm gate and from the on-farm application of that water to the crop root. Figure 13 demonstrates that only a fraction of the water that is diverted from the Indus River System reaches the crop. Conveyance losses within the canal system account for an average of 25 percent losses to the watercourse outlet to the farm-gate. These have been estimated at 30 percent too (Jacoby et al., 2018). This means that, of the 95 million acre-feet (MAF) of water diverted from the Indus River System 24 MAF is lost in canals through seepage and evapotranspiration. This leaves 71 MAF at the canal outlet (*mogha*) level. From there, an estimated 30 percent is lost in tertiary watercourses leading to farms—these are often unlined. This means that of the 71 MAF available at canal outlets, another 21 MAF are lost till the farm-gate. But each farm has multiple fields within it which receive water for cultivation.

**Of the 95 MAF diverted from the Indus River System to the irrigation system, only 50 MAF is available at the farm-gate.** Farmers draw about the same amount of water from the Indus aquifer through tube wells. But field losses are in the range of 35 percent so only 65 MAF is available to farmers. Traditionally, water is applied through flood irrigation methods. Lack of laser land levelling is a key reason for over-watering in large parts of Pakistan's agriculture landscape. If the land is not suitably levelled, the plants in a trough on the surface will suffocate with too much water and the plants on a crest on the land will have low water availability. Farmers typically water their fields to the level required by the plants on any trough. This and other reasons for flood irrigation can result in further losses estimated at 40-60 percent in many cases (Akbar et al., 2016; Sajid et al., 2022). The monsoons add about 13 million acre-feet of water to the 65 MAF available to farmers from the irrigation network and groundwater (the Indus aquifer).

Farmers get 78 MAF for farming against an estimated crop requirement of 98 MAF. This shows that Pakistan's irrigation system is highly inefficient and requires major improvements of these delivery systems to improve water use productivity and support economic growth.

**This low water use efficiency is attributed first to the state and management of irrigation infrastructure.** This system is often flaunted as the world's largest contiguous irrigation network. But the operation and maintenance of this infrastructure is far from adequate. Celebrated water expert John Briscoe famously wrote that Pakistan's business model for its irrigation system is the 'BNR model': the Build-Neglect-Rebuild model (Briscoe & Qamar 2006). Much of the infrastructure is not being maintained and functions at low performance. For example, Pakistan largely missed the opportunity to remove the sediment getting deposited in the reservoir of Tarbela Dam. As is often quoted, Pakistan has a very low capacity for water storage. The Indus River System can barely hold 30 days of average flow compared to over 900 days for the Colorado River in the USA and the Murray-Darling system in Australia.

Tarbela Dam and Mangla Dam have reduced capacity by 29 percent and 21 percent respectively due to silting and sedimentation (Haq & Abbas 2012). The volume of sediment accumulated in the reservoir is now too large for removal to be practical. The result is that the dams can store less water stored for the dry season than the original design capacity and they can overflow during monsoons. Adequate maintenance expenditure would have maintained the storage levels close to the original level. The cost to remediate sedimentation in Tarbela Dam would have been a fraction of the total annual maintenance cost of Pakistan's irrigation system. Today, the sedimentation is too large for practical removal. The more viable solution to relieve sediment build up now would be to finish construction of the upstream Diamer Bhasha Dam (World Bank, 2019).

**Flood irrigation is often used on-farm because water delivery is unpredictable** ("fill up while it's flowing!") or to keep weeds from growing right after sowing (as in rice paddy) or because soils are suffering from salinity. The result is that, it has often been observed that reductions in the amount of water typically used during irrigation actually improved water use efficiency and they could grow more by using less. In Dera Ghazi Khan, cutting water from 500mm to 250mm only decreased yields by 5-16 percent, while greatest water use efficiency was at 153mm (Jabeen et al., 2021). But the unpredictability of water for farmer is linked to the approach of Pakistan's irrigation system to water delivery.

## The irrigation system is supply-driven rather than demand-driven

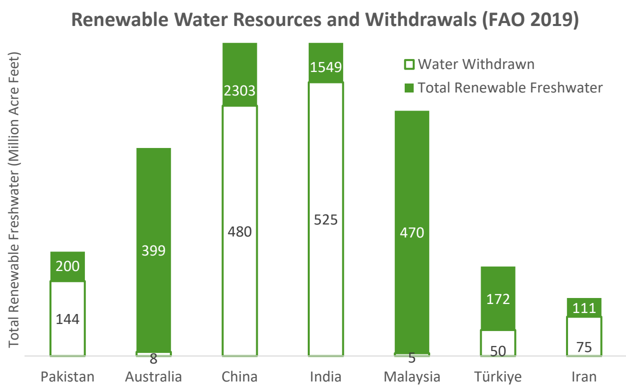
In agriculture, water delayed in water denied. If plants do not receive water at the times they require water (and fertilizer which is delivered with water), they cannot grow optimally. This impacts yields and therefore growth in agriculture. The *warabandi* system of fixed-turn water allocation allows farmers to take a certain amount of water at a certain time of the day once every week (or every 10.5 days). The amount of water available to withdraw is proportional to the size of the farm, not to the demand of that farm based on the requirements of its crop. Gravity-driven water distribution in the canals is often inadequate at the tail ends which, on average, only receive 60 percent of designed supply (Mirjat et al., 2017). This is not only because of technical reasons but also due to water theft by more powerful farmers in connivance with irrigation officials. Canals typically perform less adequately in early-summer low-flow situations averaging 25 percent less than their designed supply. Farmers that require frequent watering to support different stages of crop growth or who are at the canal tail are then forced to address demand by pumping groundwater, which is not regulated under *warabandi*.

An example from the canal tail illustrates this point. Pakistan's capital of red chili cultivation is Kunri, in Sindh's District Umerkot, where the uniquely round *dandicut* (or *longi*) variety of red chilies are grown because growing conditions are ideal. But water is the limiting factor. When seedlings are transplanted onto the field, they require frequent watering to establish roots, more frequently than *warabundi* currently provides (Pakistan Planning Commission, 2020). In the drought conditions of 2018, mistiming of water supply compounded with low flows at the canal tail end which left red chilli farmers with no ability to achieve their expected yields. With no reliable groundwater in the District Umerkot area to compensate for the lack of canal supply, cropped area was reduced to 40 percent (Daily Dawn, 2018).

## Groundwater from the Indus aquifer is critical for Pakistan's agriculture

Pakistan has an estimated 200 million acre-feet of total renewable freshwater including groundwater sources. As figure 14 shows, Pakistan withdraws over 70 percent of these freshwater resources each year which is among the highest among comparator countries in the world (FAO AQUASTAT 2019). China and the India both withdraw more water every year than Pakistan, but only 21 percent and 36 percent of their total freshwater resources, respectively. With an enormous proportion of water being withdrawn for Pakistan's agriculture, water use efficiency in both irrigation and agriculture must be prioritized.

Figure 14: Pakistan withdraws more of its water



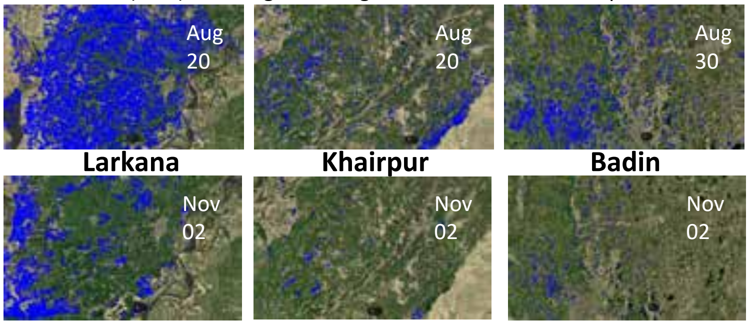
In the areas that are now Pakistan, modern irrigation started in the 1860s. Over the subsequent decades, substantial amounts of water seeped through the canals and added to the Indus aquifer. Over time, the groundwater table rose from over fifty feet below the ground surface to ten feet below the surface causing issues of waterlogging and salinity in the 1960s. These issues were addressed through the Salinity Control and Reclamation Project (SCARP) which introduced over 12,000 public drainage tube wells to control the groundwater table and release the freshwater back into the canal system. This was an ingenious way to draw water out of the Indus aquifer while putting it to good use. The program succeeded in reclaiming waterlogged lands and simultaneously increased the water supply which improved cropping intensity. In the 1970s, performance issues of the public wells and increasing operational costs forced the program to transition towards subsidizing the installation of private tube wells for farmers. There was already growing interest from farmers who wanted continuous access to the very shallow aquifer at that time. This sent the pendulum swinging far in the other direction leading to a rise in the number of tube wells in Pakistan from 30,000 in the late 1960s to over 1.2 million in 2020 (Qureshi, 2020). Today, Both Pakistan and India are drawing water from the Indus aquifer faster than the rate of water re-charge back into the aquifer. This is leading to a lowering of the water table. Neither the Indus Water Treaty of 1960 with India nor Pakistan's inter-provincial Water Accord of 1991 deal with the allocation of groundwater from the Indus aquifer. Both instruments should be upgraded to make them comprehensive.

**Farmers are protesting against rising electricity tariffs for tube wells because groundwater is nearly half of farmers' water supply today.** Pakistan is the world's fourth largest user of groundwater and meets nearly half of the irrigation requirement with groundwater (Khalid & Qaisrani, 2018). Nearly 90 percent of the tube wells are in Punjab due to lower salinity and relatively higher water quality. Most of Sindh has saline groundwater which means that any water that flows into the aquifer is lost forever. However, the relentless pumping of groundwater has now lowered the water table back to or below pre-colonial times. Canal tail users are caught in a feedback loop of increased reliance on groundwater when canal water is insufficient, but also are farming in the reaches of the aquifer that are least fed by seepage. The cost of pumping from a shallow well (less than five meters) is US$4.5 per thousand cubic meters versus US$15 from a deep well (more than twenty meters). The cost of installation of an electric deep well is ten thousand dollars versus one thousand dollars required for a shallow well. Increasing fuel and energy prices have also increased operational costs, straining the farmers' ability to withdraw needed water.

**Irrigation is not just about delivering good water—it is equally about removing bad water safely so that soils are healthy for the next crop.** But effective drainage is a challenge in Pakistan. The failure of the cotton crop in 2020 was caused by a combination of pink bollworm attacks and excessive, untimely rains. The lack of drainage meant that rainwater stood and devastated crops.

Figure 15: Which district has more effective drainage?

Water (blue) standing after August 2022 floods in Sindh province




*Source: Satellite images from Pula Advisors (2022)*

Fields that do have drainage infrastructure have, in some cases, released agricultural run-off into key water bodies that have been rendered unusable. The most extreme example is Manchar Lake in Sindh province which has been so polluted by the Right Bank Outflow Drain that fish populations have plummeted, and the health of the local people has suffered (Mahesar et al., 2019). Fields that do not have drainage or have been impacted with secondary salinity require contaminant flushing through irrigation, pumping of unusable water, or abandonment of the field.

## Drainage and water quality are critical issues to address

**Neglected water quality is harming health and is a threat to agricultural exports.** Surface and groundwater downstream of tanneries on the Sutlej River have shown severe levels of water quality degradation thereby affecting human health, ecology, and local agricultural production (Atique et al. 2020). Effluent from leather tanning production re-enters soil and surface waters as recycled water from the wastewater treatment plant (Abbas et al. 2012). This contaminated groundwater has led to increased cases of water-borne diseases such as typhoid, cholera, cancer, kidney failure, and more (Ali et al. 2022).

Pumped groundwater is increasingly drawn for household and drinking use, particularly where water supply is limited or because it is safe from microbiological contamination. However, this groundwater often contains unsafe concentrations of total dissolved solids and heavy metals. Water quality indices show that groundwater in Sindh is most often unsuitable for drinking purposes based on WHO standards from Larkana to the Thar Desert (Lanjwani et al., 2022; Jamali et al., 2022; Khuwahar et al., 2019). Surface water quality is also deteriorating, caused by untreated effluent from industry and agriculture.

The Chenab River, for example, receives waste from the industrialized city of Faisalabad, agricultural run-off from adjoining agricultural districts. The downstream stretches of this river are highly polluted. The poor quality of the Chenab's water is particularly acute during low flows, when concentrations of effluent are much higher relative to freshwater input (Kausar et al. 2019). With less flow in the river due to upstream withdrawals, this can harm those who use the nearby water, illustrating another reason why appropriate management of canal diversions is crucial.

## Climate change is expected to seriously impact Pakistan's water resources

The flow of the Indus River System is controlled for much of the year by glacier (permafrost) melt and snow melt, while fluctuation in monsoon strength has a large impact on peak flows in summer months. Climate change will have varying effects on both natural inputs, increasing glacier melt and altering the predictability of monsoonal rainfall. The projections of glacier melt are not yet an exact science but there is emerging consensus that melting glaciers may increase flows in the short-term, but flows may decrease 30-40 percent in the later part of the 21st century (Habib & Wahaj. FAO. 2021). Projections for rain indicate large year-on-year variability suggesting increased volume of rainfall on fewer rainy days (Parry et al. 2017), as is already evident by recent intense drought and heatwave periods followed by flooding. Sindh had received 30 percent of the usual rain during the monsoon season in 2018. Just four years later in 2022 the province received rainfall that was more than 500 percent above the average for the monsoon season (Pakistan Meteorological Department). An added challenge to water resource management will be: how to adapt to the changing conditions of extreme weather events given the state of glacier and snow melt.

## Conclusion and policy priorities

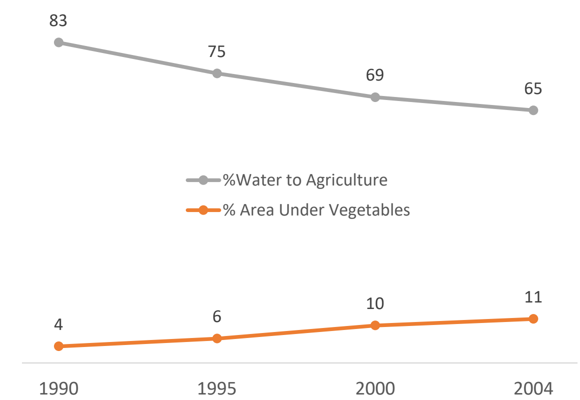
**The highest priority of this decade must be to reduce water wastage** both in the irrigation system and on-farm. The focus of Pakistan's public discourse on water has been dominated by the construction of dams. While adding more water storage is critical, the more mundane activities need to be performed with care and integrity.

**Pakistan's irrigation system needs a serious upgrade.** Pakistan's overall water productivity is low because of the massive water losses in canals, tertiary watercourses, and on the farms. The major challenge of conveyance losses from canal delivery will require substantial interventions in policy, governance, and infrastructure improvement for these on-farm actions to succeed. Farmer choices to flood irrigate, overdraw groundwater, and plant crops with low water productivity is highly influenced by the unreliability and low financial performance of current irrigation system. Priorities are needed to improve lining and drainage where the most benefit can be achieved from waterlogged and saline areas. Canal lining efforts have proved successful, for example, in Mirpur Khas where cultivated land nearly doubled off some watercourses after canals were improved (Zaidi et al., 2022). Increasing the value of canal water will require a comprehensive water monitoring and metering system that can properly account for the movement of water within the system. To recuperate operation and maintenance costs, an equitable pricing system will need to be developed based on transparent and precise quantities of water delivered to farms, particularly small farms and farms at the canal tail. Better governance of irrigation is the key.

For each crop, the water productivity is low partly because of low crop yields but also because of the significant on-farm wastage of water primarily through flood irrigation. Water pricing is unlikely to shift the crop choices of farmers without resolution of major challenges in crops like cotton. But it is reasonable that water pricing is set to at least collect the operational and maintenance costs of the irrigation system. The fact is that farmers' opposition to even this level of increase in the price of canal water is because they do not earn enough from their crops. The yields are too low for Pakistan to charge a reasonable price.

**Pakistan's acreage under horticulture (fruits & vegetables) must rise from 5 percent to 15 percent.** The domination of Pakistan's cultivable acreage by only five field crops means that these crops significantly dominate not only land but also water, human resources, etc., as well. China's historic shift between 1990 and 2004 from four percent of its acreage under horticulture to 11 percent of its acreage under horticulture created a global boom in the production of dozens of fruits and vegetables. This period saw China's water devoted to agriculture fall from 83 percent to 65 percent. Pakistan must increase the proportion of its cultivable acreage under horticulture from 5 percent to 15 percent within this decade. The introduction of high efficiency irrigation systems on these orchards must be supported financially.

Figure 16: China: Rise in vegetables led to fall in water use




*Source: World Bank, FAO*

**High efficiency irrigation systems must spread further to generate more value per drop.** These systems include drip irrigation, sprinkler irrigation, center-pivot irrigation, etc., which have application efficiencies and yields much greater than flood irrigation. For example, drip irrigation applies water and fertilizers close to the crop roots as per the plant's requirement, wetting only a fraction of soil surface therefore reducing water lost to evaporation. Application efficiency for drip is consistently above 90 percent and increases yields between 20 and 40 percent for cotton, sugarcane, and wheat (Sajid et al., 2022; Baksh et al., 2015, Singandhupe et al., 2008; Aujla et al., 2005). Cost and know-how are the largest barriers to adoption of high efficiency irrigation though, with World Bank support, Punjab and Sindh have developed their own provincial projects to subsidize costs.

**Laser levelling must become a norm across Pakistan's cultivated area.** Laser levelling is a crucial step in preparing efficient fields such that water is evenly distributed without pooling or major runoff. In Sargodha, laser levelling improved water use efficiency by 33-38 percent, increased yields 6-10 percent, and supplemented incomes by 32 percent after including costs (Ashraf et al., 2017). Laser levelling in upper Sindh is critical to save water but even the initial earth moving works have not been conducted on farms there after which laser levelling can start its work. This initial activity must be encouraged so that. On farm storage developments accumulate excess water and help farmers address water insecurity for farmers when canal flows are low. They may also help with addressing water quality by draining excess water during heavy rain, controlling soil erosion, and recharging groundwater in the nearby vicinity.

**The Indus aquifer must be safeguarded.** The withdrawals from the Indus aquifer are faster than the water re-charge to it. The Indus Water Treaty of 1960 with India and Pakistan's inter-provincial Water Accord of 1991 must be upgraded to deal with the allocation of groundwater from the Indus aquifer.