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Agricultural Water

Free Flowing Markets Sustain Growth

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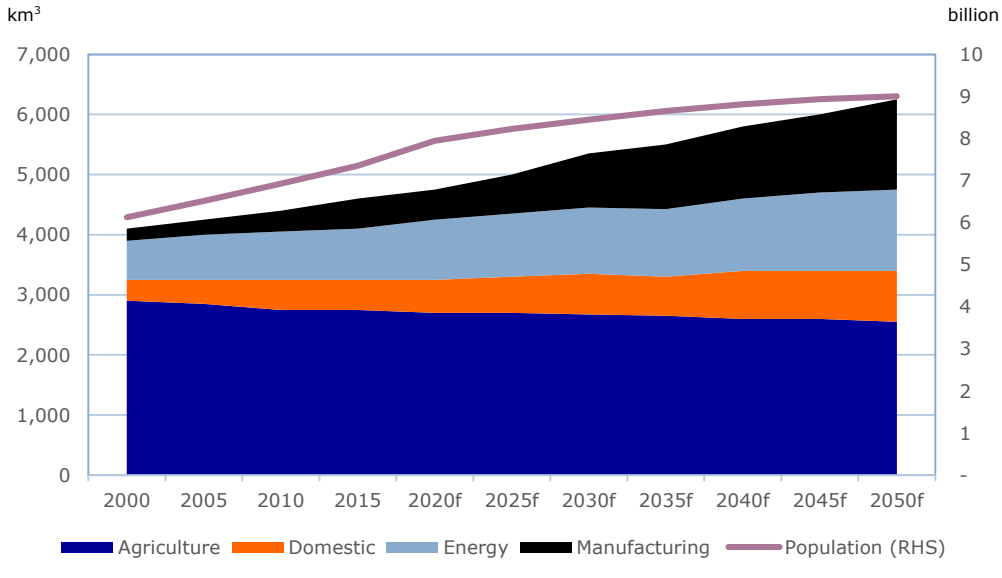
- **Unless public and private investments are made in better water management throughout the world, a 40 percent global water deficit is expected by 2030.**
- **More robust water markets will lead to more economically efficient water allocations and investment, but government intervention is needed in order to control unintended costs to society.**
- **Newly industrialised countries have worked to solidify and advance governance with regard to water. Political stability, property rights and government advancement will help these regions improve their current situations.**
- **Expansion of water markets will make water less affordable for some ag producers, especially smaller farmers, but will decrease water uncertainty for ag as a whole.**
- **Continued expansion in the use of transparent water markets will lead to more economically efficient water allocations, encouraging needed investment and better water management.**

Contents

Introduction: water challenges and opportunities

The world must increase its usable water supply and effectively manage water demand, while ensuring that everyone has access to enough water to meet their basic consumption and sanitation needs for survival. These tasks must be balanced with providing rural communities and the agricultural industry access to enough water to be economically viable and to feed a growing world population (*see Figure 1).*

Figure 1: Global water demand will continue to increase as the population grows, 2000-2050f



Source: OECD, 2008; United Nations, Rabobank, 2016

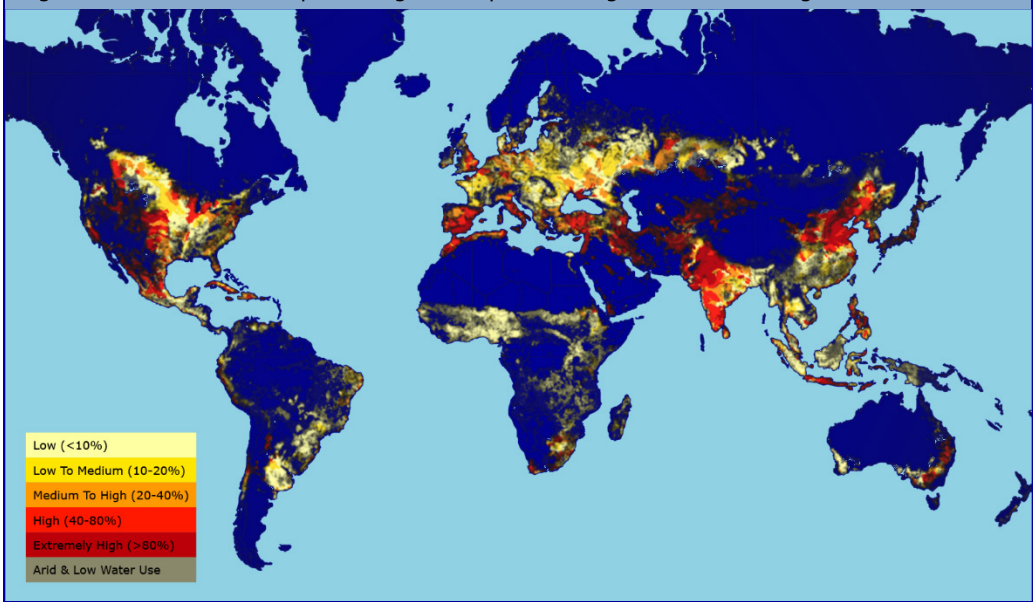
At the same time, global economic development requires enough water to support increased demand for energy production and industrial use. Additionally, water must be used to maintain ecosystems and other natural amenities. All of these competing needs must be met, against a backdrop of increasing climate variability. Proper allocation of existing water resources is critical. The challenge is in determining what the 'proper' allocation should be, along with incentivising investment so that use-efficiency technologies and supply-side infrastructure are not underprovided. 'Free' markets have been shown to be a capable mechanism for efficiently allocating resources to their highest value use, including the allocation of capital investment.

The global water allocation dilemma

In 2010, the United Nations (UN) explicitly declared that access to safe drinking water and sanitation is a basic human right, which formalised an earlier declaration that everyone has a basic right "to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses". In 2014, the UN estimated that roughly 3.5 billion people's basic water and/or sanitation rights were not being met. While basic access to safe and affordable domestic water and sanitation is primarily a third-world problem, increasing climate variability can even create this basic challenge in the most developed regions of the world. To compound this challenge, the global population is expected to reach 9 billion by 2050.

The populations in Africa, Asia, Europe, Latin America and the Caribbean, North America, and Oceania are, respectively, going to increase by 95 percent, 10 percent, -11 percent, 13 percent, 13 percent and 34 percent. Africa—specifically sub-Saharan African countries—will be faced with some of the most difficult challenges associated with this rapid population growth and subsequent urbanisation. As countries continue to develop, greater incomes will be achieved, increasing food consumption and putting additional pressure on agriculture producers and water, especially in major food-producing regions (*see Figure 2)*.

Figure 2: 2013 estimated percentage of cropland facing water stress—a global dilemma



Source: World Resources Institute, Rabobank, 2016

Energy also requires water—whether it is hydroelectric power, or water used to mine fossil fuels or to run an electric plant. With further economic development, industrialisation will continue to occur, creating greater pressure for agriculture users. Major food production regions face—and will continue to face—scrutiny over how water is allocated and used. Establishing markets to manage water will be essential when it comes to providing enough water to grow the food necessary to sustain 9 billion people by 2050.

Water and food security are important to every country; however—because of geographic location, urbanisation, industrialisation and growing populations—they are becoming more relevant and apparent to some regions, including, but not limited to, Sub-Saharan Africa, Chile, Brazil, China, India, South Africa, Mexico, the United States (US), New Zealand and

Australia. Water challenges or water stress can happen to almost any given country, regardless of location or historic water availability.

From the Americas to Australia: water management needs change

Challenges arise when the availability of a critical resource—in this case, water—is limited and doesn't meet the needs of all of its users. Unless prices for water accurately reflect its scarcity, users will demand more than the amount available. Different, water-challenged geographic areas each have a specific set of geological, economic, political, social and technical circumstances, which lends some uniqueness to their potential solutions. However, their general challenge remains the same: to effectively balance the supply and demand of water for both current and future generations.

Depleting basins in North America

North America, in general, is considered 'water-rich'; however, specific areas are threatened by the overuse of surface and groundwater, particularly in the Great Plains region and the western half of the US. Three of the agriculturally relevant regions, in particular, facing water challenges are the Colorado River Basin, the Ogallala Aquifer and California.

The Colorado River Basin: overcommitted

The Colorado River Basin extends from the south-western corner of Wyoming through Utah, Colorado and Arizona, stretching into New Mexico, Nevada and California, and ending in Mexico. Historically, the water has been divided between these states—respectively accounting for 2 percent, 11 percent, 23 percent, 17 percent, 5 percent, 2 percent and 27 percent—while Mexico receives 9 percent of total water allocations. The US and Mexico signed a treaty, allocating some of the water to Mexico for its needs. The basin is divided into upper and lower regions, separation being the north-eastern corner of Arizona. Over 80 percent of the water delivered is used for agricultural purposes. Increasing demand from agriculture, municipal and industrial users severely threatens the sustainability of the Colorado River Basin. As drought has significantly impacted a large portion of the western US, users have relied more on the water stored behind dams along the Colorado River. This has further depleted the available supply of water. Historically, users in the Lower Basin—mainly Arizona, California, New Mexico and Mexico—have used more than their allotted share of the water, while those in the Northern Basin have used less. But because the basin is being overcommitted, it is likely that Lower Basin states will have to purchase the rights of those in the Northern Basin—or significantly reduce their water usage. Not only is the river being threatened by overconsumption; it is also facing the effects of climate change. Increased temperatures in the south-west are constricting the amount of water available. The US Bureau of Reclamation predicts that a 20 percent decrease in runoff could lead to a 60 percent or 70 percent decrease in storage, along with a 15 percent increase in salinity.

The Ogallala Aquifer: fragmentation drives difficulty

The Ogallala Aquifer is a name for thousands of smaller aquifers that stretch from South Dakota into Texas, reaching into Wyoming, Nebraska, Colorado, Kansas, New Mexico and Oklahoma. Within the Ogallala Aquifer, irrigation is provided for livestock production, along with wheat, cotton, sorghum, sunflowers, soybeans, corn and other crops. The fragmented nature of the aquifers makes it very difficult to manage from water district to water district—and even more difficult from state to state. This fragmentation allows for little, if any, subterranean flow between many parts of the aquifer. Due to the lack of continuity of flow and the aquifers spanning such a large political/geographical area, macro-management is virtually impossible.

The variance between different states and water districts makes managing allocations very difficult. The specific geographic location of a producer could limit the amount of water available to that individual. But many of the aquifers in Nebraska are currently at higher water levels than they were before significant well-drilling began; meanwhile, the north-western part of Kansas has significantly more problems than southern Kansas, Oklahoma or even Nebraska. This is a cause of friction between Kansas and Nebraska, where a geological structure prevents any underground movement of water. The solution is a pact that allows water to flow overground, away from farmers in the Republican River Valley in Nebraska to those in Kansas. The fragmentation has also led to other challenges where, in many cases, one state does not care what another does. There are internal state laws, unintendedly allowing localised areas to dry up—through 'race-to-the-bottom policies', where farmers

own whatever they can pump in Texas, while in Kansas, they are limited to water shares. But even these nuances can vary from water district to water district within a single state.

In Nebraska, Oklahoma, Texas and Kansas, only between 15 percent and 20 percent of the combined acres of corn, soybeans, wheat and cotton—representing the largest crops—are irrigated. Of this, 12 percent of US corn production stems from Nebraska—where water is less of a problem—while only 5 percent comes from Texas, Oklahoma and Kansas combined. Perhaps the biggest challenge will be for cotton and other heavily water-dependent crops. Texas produces between 30 percent and 45 percent of US upland cotton, of which between 30 percent and 35 percent is irrigated.

In a 2013 study published by Kansas State University, it was estimated that, between 1960 and 2010, nearly 30 percent of the total volume of the Ogallala Aquifer had been depleted. If the use of water continues at a similar rate, the projection is that, by 2060, nearly 70 percent of the aquifer's total available water will be tapped. Limiting the amount of groundwater used for irrigation, or improving irrigation efficiency, will be key in helping to sustain this aquifer. In much of the region, irrigation is supplemental, in contrast to areas further west. This suggests that rain-fed farming—with no supplemental irrigation—could eventually re-emerge and be viable in some places that are currently focused on grain production with supplemental irrigation.

California: changes are underway

California has been referred to as the 'food basket of the world', and the state is responsible for growing over 400 different commodities and producing nearly half of all US fruits, nuts and vegetables. The four-year drought in California has left many rural households with dry wells and more limited income opportunities (particularly in agriculture), which further limits their ability to afford access to water through alternative means. The drought has forced Californians to create policies which will help manage and replenish basins in the future. (We offer a detailed discussion of California's current water policies and management further on in this industry note.)

Latin American countries: more comprehensive strategies are necessary

Latin American countries have different geographical and political situations that make each country's challenges unique—from 'water-rich' Brazil to parched Mexico. The following three countries have a large agricultural industry and are currently facing water-related challenges:

Brazil: 'water-rich'—a blessing and a curse

Brazil is historically a 'water-rich' country and, as such, has only recently begun to develop formal policies regarding water rights. Until recently, there was little need to ensure that the growing population and agricultural users had adequate water for their needs; however, this has been problematic, as the country has recently been exposed to a severe drought in some regions, particularly in the south-east. Brazil's primary agricultural production region lies in the south-central portion of the country, while a majority of its water lies in the Amazon basin in the north-west, with a majority of the population living along the eastern coastline. The responsibility of water management has been delegated to the 27 states and the federal district. Current infrastructure is inadequate to manage the use of the river basins. Effective communication and collective management between states is necessary to develop a sustainable water market. It wasn't until 2006 that every state within the country had detailed laws and policies regarding the use of water. Only a few states are in the advanced stages of implementation of their water management systems. Despite rainfall recovery in late 2015, the 2014 Brazilian drought has forced cities and local governments to update and maintain current water conveyance systems to ultimately protect and manage water for both urban and agricultural users.

Chilean challenges: the Copiapó Aquifer

Water law reforms were enacted in Chile more than 30 years ago; however, water management practices have been in place for over 100 years. The law accounts for water as a public good, but also allows individual users to purchase, trade or inherit water rights. At the time of enactment, these laws were unique in that they limited the state's ability to intervene in the management of water. The objective of this law was to create a water market, which would effectively set a price that reflects the true value of the resource. But less than effective governance is in place, which is a direct result of 42 independent units

that regulate water in some way. They unfortunately block each other and cause gridlock, resulting in little synergy between the agencies.

When the laws and right reforms were passed in 1981, the government overallocated water permits, assuming that only a small percentage would be used in any given year. At the time, there was insufficient data, due to a lack of studying total available water. As agriculture has grown in the country and more severe weather patterns have emerged, more people are exercising their right to draw on their water allocations, and this is accompanied by political misapplication of water deliveries—ultimately causing the system to be overdrawn.

This is particularly true with the Copiapó Aquifer, a major ag-producing region in Chile, where, in 2010, nearly 80 percent of the water being used was for agricultural purposes. Although Chile enacted water laws over 30 years ago, an overallocation of permits and a lack of government oversight have severely diminished the ability to effectively manage the country's water resources.

Mexico: management matters

Mexico—like many other countries—possesses areas that have water management systems and others that do not. In the early 1990s, the Mexican government established a National Water Law. At present, the UN notes that there is a comprehensive legal system, a water authority and a functioning water rights system in Mexico—all of which are important for sustainable water systems. However, in many parts of the country, water continues to be a challenge, as groundwater management is insufficient, and adherence to water governance is inadequate for a sustainable water system.

North-western Mexico is heavily dependent on the Colorado River, and the challenges impacting it in the US are also impacting farmers in Mexico. Increasing upstream demand and general overcommitment of the river’s flows will become increasingly challenging to Mexican producers who rely on it. In order to sustain this body of water, further international discussion will need to take place.

Groundwater overdraft is a serious problem in many regions of Mexico, including the agriculturally relevant state of Guanajuato. This state sits over the Silao-Romita Aquifer, home to over 20 percent of Mexico’s wells—which are continuing to be dug deeper. In this region, heavy metal contaminants are becoming an issue, and, according to reports, land in some areas is sinking 2 metres to 3 metres each year.

As in other countries in Latin America, water is overexploited in both the rivers and groundwater basins in Mexico. A lack of infrastructure and sufficient governance are some of the greatest challenges facing Mexican water users—hindering the development and enforcement of laws and policies. Ag water users are competing directly with rapid urbanisation. As water continues to be overdrawn, the quality continues to degrade. The challenges facing Mexico are not inherently unique; however, changes will need to be made to entice private-sector investment, and replenish and restore both groundwater basin and reservoir levels.

Sub-Saharan Africa: balancing politics and progress

The UN estimates that more than half of the world’s population growth between 2015 and 2050 will occur in Africa—adding approximately 1.1 billion people. Currently, in this same region, over 200 million people lack access to clean water, and even more do not have sufficient water for their basic needs. In Sub-Saharan Africa and similar developing regions, water is often used by whoever has the capability of capturing it—whether by pipe, well or vessel. However, these captures typically conform to local, customary arrangements, which provide some level of localised equity and predictability in water supply. These customary approaches are not necessarily protecting the region against groundwater overdraft, and they can slow third-party investment in water management technology and infrastructure. Some African countries have adopted legislation and policies, which are designed to offer investors transparent and protected land rights and water allocations. Balancing the implementation of these more formal, civic law-based strategies with the customary rules that many subsistence-based producers rely on continues to challenge the region. Additionally, the political instability in many of these countries hinders their ability to put long-term policies in place to adequately assign and enforce water rights.

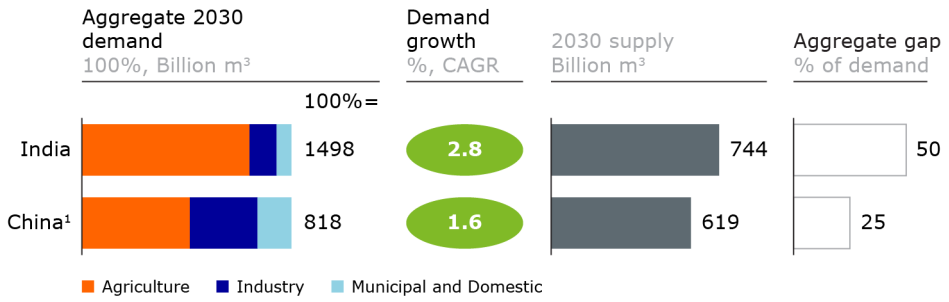
According to the United Nations Environment Programme, nearly every country in Sub-Saharan Africa shares a river basin with its neighbour. Of these, a majority have an international treaty in place to help protect the country's water rights; however, within that framework, many countries do not have institutions or funds to manage how water is used. Oftentimes, water is only available to the person who can collect it—whether for health and sanitation, agricultural or industrial purposes. The absence of rights and enforcement ability causes overdrafting to be a major problem in the region. Many countries in this region also face challenges when creating water storage or other technical developments, as these can require a significant amount of financial investment.

In rural Africa, many of the wells that are in place perform below their potential, as they were poorly designed or have not been maintained. Some parts of Sub-Saharan Africa rely on shallow, hand-dug wells, which are more susceptible to contamination. The World Bank stated that there is "very little formalised conjunctive use of surface water and groundwater [...] and groundwater resources are all too often developed anarchically (both by public utilities in response to water-supply crises and individual private users in an attempt to meet deficiencies in mains water supply), with far from optimum use of each, even in areas which are drought-prone and water-stressed". The need for adequate water development and management is there; however, the lack of governance and investment proves challenging when attempting to establish markets.

Asia: assessing future water policies

Much of Asia struggles to maintain adequate water for basic health and sanitation purposes, much less for agricultural purposes. But China and India have both climbed the economic development ladder, and both are experiencing significant increases in urbanisation and industrialisation—adding to the growing water demand. In a business-as-usual scenario, both countries will face significant water deficits by 2030 *(see Figure 3)*. Both regions have recently begun experimenting with water rights to determine the best market-based solution for water management.

Figure 3: China and India water consumption surpasses availability at current utilisation rates



¹ Gap greater than demand-supply difference due to mismatch between supply and demand at basin level

Note: Full chart available at www.2030wrg.org/publication/charting-our-water-future.

Source: 2030 Water Resources Group, Rabobank, 2016

China: changing course

While China is home to 20 percent of the global population, it possesses just 10 percent of the world's arable land and just 6 percent of available fresh water. China's per capita water availability and its available water per hectare of cultivated land, are, respectively, one-fourth and two-thirds of the world averages. Over the last 20 years, the country's water consumption has increased between five percent and seven percent annually, with agriculture using approximately 60 percent of available water. During this same period of time, China has been overdrawing rivers and groundwater basins to meet its growing water demand. The challenge is, in part, due to a significant geographical imbalance in water resource availability and demand. Northern China holds 46 percent of the country's population and 60 percent of its cultivated land, but only 20 percent of its available water. Subsequently, growing demand for both energy and urban consumption are directly competing with agricultural purposes. Through the construction of water conservation facilities, along with the promotion of more efficient practices and technologies, the Chinese government's goal is to lower ag's percentage of water use to 55 percent by 2020.

In many regions, irrigation is heavily dependent on groundwater. Due to ongoing excessive usage, land subsidence and other potential ecological challenges are becoming a concern. Additionally, the heavy reliance on a declining water table will ultimately lead to greater soil salinity and subsequent yield loss. As in many other areas of the world, China's irrigation efficiency can also be improved. Only 40 percent to 45 percent of existing irrigation systems possess water-saving technologies and strategies, such as micro-irrigation or canal seepage control techniques. According to the government's plan, the ratio should reach 60 percent by 2020. Water-saving irrigation systems can also help improve the efficiency of fertiliser and agrochemicals.

Available quantity and geographic distribution are not the only water challenges in China. While Southern China has access to a disproportionately high quantity of water relative to the north, the availability of quality water is an issue in both regions. Chemical and metal residual is a major concern, as a result of both soil contamination and water pollution.

China's centralised government has allowed for greater control of water allocations to determine how water is distributed between sectors. The centralised government also takes the responsibility for water storage and management. China has begun test programmes within seven provinces to pilot a water allocation programme. The programme attempts to address the increasing environmental and agricultural concerns. As this programme has only recently been implemented, it is hard to tell what its effect will be—though there is potential for this market system to sell surplus water to those entities or regions in need of it. The government is also in the process of building over 100 dams of various sizes across the country. The ability to store and manage water will be helpful as water markets are established; however, the environmental and ecological effects of those dams have yet to be measured.

China's rivers not only feed the agriculture within its own borders, but they flow into India, Vietnam, Thailand and other south-east Asian countries. China ultimately controls the downstream flow and potential pollution of the river, which has been a source of tension in the region.

India: need to keep tech in check

India, China and other countries have been—and are competing to be—the first to build dams along rivers that cross international borders. China has the upper hand, as the rivers start within its borders. However, this causes political tension, as both India and China are in need of water. A lack of treaty and communication will be detrimental to properly managing and replenishing these water systems. If water withdrawals and use continue in a similar fashion, the International Finance Corporation estimates that, by 2030, India will likely have a 50 percent water deficit. If nothing is done, these systems will likely be overexploited and heavily polluted, encumbering sustainable water markets.

Within the last two years, India's management of water rights has been delegated to individual states within the country. Local governments act as the institutions that manage water consumption. Although the states have the authority to oversee the use of water, they lack the ability to effectively measure or enforce such use.

A majority of India's water infrastructure and development revolves around groundwater. It is estimated that between 70 percent and 80 percent of the country's agricultural output is dependent on groundwater. Many northern Indian states have debated groundwater laws for over 30 years, with minimal progress. In Gujarat—a rural state—electricity is subsidised, and groundwater is 'free'—thus the basins are overdrawn, which is an all too common scenario in India. Providing energy subsidies to agriculture users ultimately limits the amount of water available for industrial or agricultural purposes, as wells continually need to be dug deeper. In this particular instance, the availability of technology (wells with electric pumps), combined with lack of management, has delayed the development of a more balanced and sustainable water sector.

Oceania: a tale of two island nations

Oceania is a series of islands comprised of over 30 countries—from Guam to French Polynesia—all of which have unique agricultural situations. Nearly two-thirds of the islands' population lies within Australia and New Zealand. These two island nations are also hubs for global agricultural production. Both are inherently different in their current water situation—

New Zealand being 'water-rich' and Australia less so. However, water management is becoming an integrated part of each of their respective societies.

New Zealand: blessed by nature, but still needing to embrace change

A country that is the envy of much of the world when it comes to its abundant water resources and environmental management outcomes, New Zealand hasn't had to develop and regulate use of its water resources as actively as many other countries. But New Zealanders are not altogether immune to the need to embrace change—to ensure that the competing demands of society, the environment and agriculture can all be planned for and managed in a sustainable way in years to come.

In addition to growing regulations to monitor and control farm runoff into waterways, the growth of New Zealand's agriculture sector has also led to mounting demands on the volume of water required to be diverted for irrigation. Public and industry concerns led to the formation of a broad sector group for consultation, which resulted in government legislation: the National Policy Statement for Freshwater Management. This requires regional authorities to measure the capacity of local waterways and groundwater withdrawals for irrigation, all in order to determine the sustainable level of diversions for agricultural and urban use—both now and in the future.

Ultimately, this may lead to some irrigators having part of their (often unutilised) rights pared back, and, in some other cases, it may present the option to issue additional diversion rights to irrigators. While this will require agricultural producers to better monitor and report their water use to authorities, the confirmation of their drawing rights should ultimately lead to a more definite value being placed on water-use rights, as limits on supply are determined and regulated. In those parts of the country where water security is less assured throughout the growing season, irrigators may need to acquire additional rights, implement water saving reforms and/or increasingly look into the case for investment into new central irrigation schemes that leverage abundant regional catchments.

Australia: adversity is a turning point

Australia recently faced a decade-long drought, which tested the ability of government policy, institutions and markets to adequately plan and provide for reliable access to water. Faced with the harsh reality of crippling droughts, government officials and citizens were forced to re-regulate and invest heavily in order to protect the productivity of agriculture, as well as the sustainability of waterways. (A closer look into their path to water management will be discussed later in this note.)

Whether a developed or a developing economy: change is needed

Globally, many developed countries have—or are implementing—water markets; however, stages of development differ by country and region. In the US, water rights have been assigned to the Colorado River Basin for nearly 100 years; in California, surface water rights are similar, while groundwater management is in its infancy; and in the Ogallala Aquifer, there is little management. Developed countries benefit from a strong government structure, both public and private investment, property rights and robust institutions to oversee and manage water allocations.

Countries that are still newly industrialised or are climbing further up the ladder of economic development—such as China, India, Brazil and Chile—still have work to do in order to further advance their current water market structures. Political stability, property rights, government investment and more advanced institutions will help these regions improve their current situations.

Underdeveloped and developing countries will continue to struggle to establish effective governance, as they lack the basic necessities to establish robust institutions, which are essential in creating a sustainable water allocation system. Many of these countries' economies revolve around subsistence-based agriculture, limiting their economic progression. Managing scarcity—whether water or food—happens best when governance, property rights and investment are all in place.

There are few—if any—countries in the world that don't need to make changes. Even major agriculture-producing regions that are economically advanced—such as Australia and California—have deemed it necessary to make significant reforms and investments in the

last decade in order to mitigate the effect of future droughts, replenish groundwater and improve current water allocation systems.

Australia: markets have made a positive difference

Agriculture is the largest user of water in Australia, accounting for 62 percent of water use in 2013/14. In the same year, irrigated production represented less than 1 percent of Australian agricultural area, but it consistently represents almost 30 percent of the country's Gross Value of Agricultural Production (GVAP).[1]

Water markets have played a critical role in the management of Australia's water resources since the 1980s—and nowhere more so than in the Murray-Darling Basin (MDB) in south-east Australia. Approximately half of Australia's AUD 14.6 billion GVIAP is generated in the MDB. In 2013/14, it accounted for 57 percent of the total volume of water entitlements on issue across the country. The MDB has the most-developed water markets in the country, where, on average, 85 percent of Australia's entitlement trades and more than 90 percent of allocation trades took place between 2007/08 and 2013/14.[2] The vast majority of trading activity is for surface water access—with the major sectors for irrigated agriculture in the basin including cotton, vegetables, fruit and nuts, and dairy.

The need to move away from a water rights system became clear, as existing diversion rights were seen to be placing excessive strain on the overall sustainability of the MDB. Given the fact that water respects no political boundaries, a series of political accords—such as the National Water Initiative (2004) and the Water Act (2007)—has been critical to developing a more coordinated framework through which to manage MDB water resources and to granting the necessary authority to an independent body: the Murray-Darling Basin Authority. This has provided the foundation to national water markets and public investment in reforms, which are expected to total AUD 13 billion over the period 2007 to 2024.

Water markets have provided an essential conduit through which to place a truer economic value on water resources across the MDB. This has, in turn, helped to guide future reforms. Following the key move to separate water rights from land ownership in 1994, the sophistication of markets has increased. Policy and regulation have evolved in a new era of regarding the triple bottom line of economic, environmental and social needs. These have been significant in driving water use efficiency gains by agriculture—typified by industries such as cotton that have experienced industry-wide water efficiency gains of 40 percent during the last decade. Water trading has also been helpful in managing farm incomes in the face of commodity price risk and drought.

Transforming water use in the Murray-Darling Basin

A new chapter in Australia's water story emerged as the effects of the millennium drought worsened, resulting in considerable reductions in agricultural production, and threatening the very water available to sustain cities and towns across the MDB. Furthermore, water recovery programmes aimed at diverting greater flows for the environment have been underway since 2004, with the Australian government first entering the water market as a buyer in 2007/08. These government purchases—and purchases since—have supplemented previously enacted environmental water allocation rights.

As of late 2015, 60 percent of water rights recovered from the system by the government since 2008 had been purchased back from irrigators, while a further 30 percent was saved through efficiency-enhancing investments in water delivery infrastructure programmes.[3] In recent years, the mechanism has switched—with infrastructure programmes representing a far greater share of water recovery.

The water markets in the basin are based on a 'cap-and-trade' system, in which the cap represents the total pool of water available for consumptive use. Available water is distributed to users via water rights administered by the basin states. These water rights are entitlements to an ongoing share of the total amount of water available in the system.

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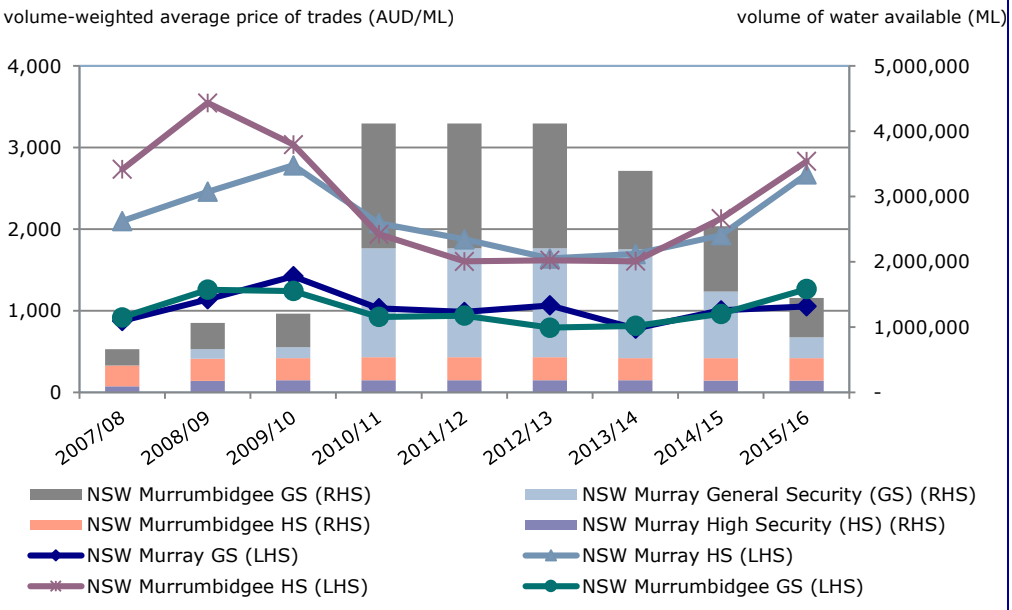
[1] ABS Water Account, Australia 2013-14, 2016
[2] ABARES Australian Water Markets Report 2013-14
[3] ABARES Australian Water Markets Report 2013-14

In turn, these entitlements are then allocated based on the actual amount of water available under water access entitlements in a given season.[4]

The price of water has traditionally been inextricably linked to availability—and, for the allocation or temporary water market supply, this will remain the major driver of price. That said, changing demand dynamics are now also beginning to exert their influence. With less water available for Australian agricultural production, those crops with higher gross margins have begun to exert their influence in markets, owing to their greater marginal capacity to pay. For example, hectares planted to cotton have expanded considerably, as has the area of permanent nut plantations.

Following the rebalancing of the system, remaining water rights now carry a greater degree of security, which is reflected in the value of permanent water rights, which have held a steadier trajectory, even after the drought came to an end and system flows were replenished *(see Figure 4)*. Importantly, these assets can now be relied upon to a greater degree as collateral for the business and as a store of value in times of low cash flow and profitability.

Figure 4: Annual entitlement prices and water allocated for major New South Wales entitlements, 2007/08-2015/16



Note: Total available water includes water allocated to entitlements held by environmental water holders. Transfers with reported prices lower than AUD 500 and higher than AUD 4,000 are excluded from price calculations for higher-reliability products, and lower than AUD 50 and higher than AUD 2,000 for lower-reliability products. Prices and volumes for 2015/16 water year are year-to-date, rather than annual.

High security: a high-priority licence to draw from a regulated stream. Seasonal allocations are typically much more reliable, making them suited to town water supplies and irrigation of permanently established crops, such as orchards.

General security: a low-priority licence to draw from a regulated stream. Seasonal allocations are much more variable, depending on seasonal storage levels and demand.

Source: Aither, 2016
(Adapted from Aither Annual Water Markets Report 2014-15. See http://www.aither.com.au/water-markets-reports.)

While a number of benefits of water trading have been documented—including the higher flexibility in water use, production and farm management—there are, of course, challenges in this constantly evolving system:

- Achieving and measuring environmental outcomes while maintaining agricultural production. What intrinsic value can be placed on environmental outcomes in order to assess competing claims?

[4] http://www.mdba.gov.au/managing-water/water-markets-and-trade

- Managing increased volatility in water markets and prices—including sustaining industry viability—in times of lower system inflows and licence allocations.

- Maintaining investment in capital infrastructure and, consequently, the gains in water use efficiency over time, as the vagaries of political and climatic changes take effect.

- The trade dynamics outlined are relevant—particularly for the Southern Murray-Darling Basin, where the connected river system and breadth of production foster transferability. The impact for other systems and regions is more challenging to realise.

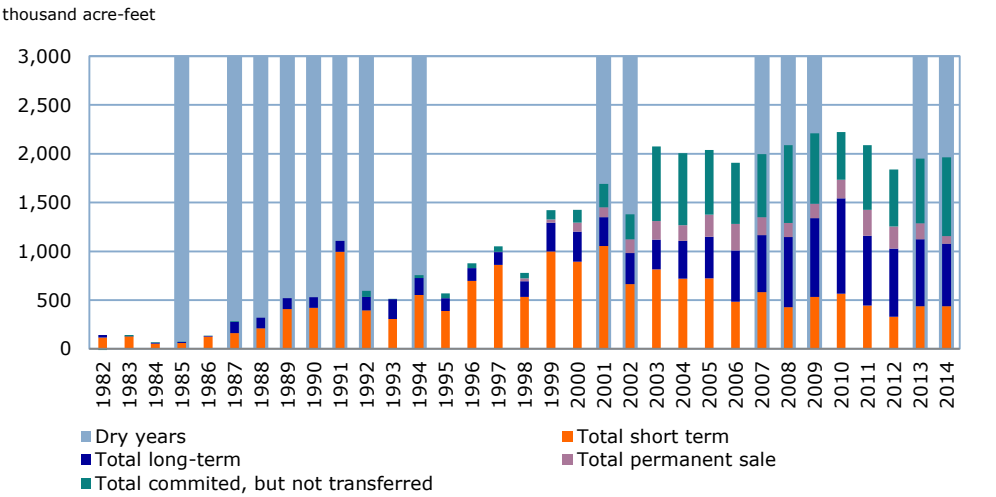
- Maintaining accurate and timely data and communications to ensure the transparency and proper functioning of water markets.

In the context of comprehensive water management and more efficient allocation of water resources from the use of water markets, Australia should be considered a success. However, achieving and measuring environmental outcomes while maintaining economically efficient levels of agriculture production has still been challenging; one of the ultimate tests of the market reforms will be if there can be more movement between environmental and agriculture demands. Balancing environmental and agricultural needs as water markets further develop will be especially critical for the world's most-productive agricultural region, California.

California: drought inspires needed reform

As represented by tree rings, the last four years in California have marked the worst drought seen in the last millennium. Yet Californian agricultural producers have continued to increase their gross cash receipts, to an estimated USD 54 billion, as a result of their increased reliance on groundwater, higher commodity prices in some key crops and incremental water purchases from other growers (*see Figure 5).* While total farm employment has continued to grow with expanded production of higher-valued commodities, it is estimated that total direct, indirect and induced full-time, part-time and seasonal employment in 2014 and 2015 would have been 17,000 and 21,000 higher, but for the drought. Costs of production—especially in the Central Valley, where most of the irrigated production is located—increased by more than USD 2 billion, due to costs associated with managing through the drought. More than 5 percent of irrigated cropland was fallowed in 2014/15. According to the Center for Watershed Sciences at UC Davis, the drought reduced California's GDP by roughly 0.05 percent in 2015.

Figure 5: Water markets are important during California's frequent droughts, 1982-2014



Note: The figure shows actual flows under short- and long-term lease contracts (orange and dark-blue bars), estimated flows under permanent sale contracts (grey bars), and the additional volumes committed under long-term and permanent contracts that were not transferred in those years (light-blue bars). The database includes transactions between water districts, federal and state agencies, and private parties that are not members of the same water district or wholesale agency. 'Dry years' are those classified as critical or dry for the Sacramento Valley, based on the California Cooperative Snow Survey.

Source: Public Policy Institute of California, 2012
(Adapted from E. Hanak and E. Stryjewski: California's Water Market, by the Numbers, Update 2012. See http://www.ppic.org/main/publication.asp?i=1041.)

While early rains—likely resulting from El Niño weather patterns—make California ag producers hopeful this water year will at least be normal, they will not fully replenish all surface and groundwater storage deficits resulting from the drought. It may take several more years of normal—or above-normal—precipitation to recover from this recent persistent drought. California frequently experiences droughts, and its weather may become even more variable in decades to come. Historically, for any particular year, there is a 25 percent probability of drought occurring and a 25 percent chance of it being an exceptionally wet year. It is the state's 1,400 reservoirs, thousands of miles of water conveyance facilities and its vast groundwater reserves that enable it to cope with drought years.

More investment and better water management are still needed

Agriculture is the largest user of developed water in California, using four times as much as cities and other industries. Irrigated crops account for more than 90 percent of the state's total crop value. Since the 1987-92 drought, municipal water districts and utilities have invested more in expanding water storage, better managing their groundwater resources, and recycling and conservation—helping them to minimise the impact of droughts on their local economies. While more than 50 percent of the state's total water flows to, or is stored, for the environment, California ecosystems have suffered significantly in this recent drought. The state's increasing population and the concern about its ecosystems will increasingly compete with agriculture for future water resources. Agricultural producers have invested in more efficient water management tools, but this has not made more water available. It has enabled many producers to increase the production of higher-valued perennial crops, increasing their vulnerability to droughts, which threatens loss of investments in orchards and vineyards. Additionally, if the climate warms as predicted, snow packs in California will be reduced, forcing water managers to find alternative ways to store winter rains. Snow packs historically account for about a third of California's water storage.

Water rights encourage investment

Most of the water rights in California are associated with land owned—and it is this investment that provides some certainty about water entitlements. Such certainty has provided land owners incentive to invest in water system management and facilities, and to advocate for public investment in water systems.

According to the state constitution, the water belongs to all Californians and is allocated for 'reasonable use'. Water use is supposed to provide benefits. Surface water rights in California are complex and comprised of three types of rights: riparian, appropriative before 1914 and appropriative after 1914. The administration of these different rights is complex and fragmented. Riparian are those rights for land owners along rivers—and such water cannot be stored or traded, as appropriative rights can. Water rights in California are generally based upon first-in-time, first-in-right, and water entitlements are capitalised in the value of the land associated with the right. Unless adjudicated, land owners generally use groundwater as much as they need—although the law does not actually authorise unsustainable levels of pumping. Additionally, there is some confusion about how much they can sell and/or convey such groundwater to others, or to other locations. Groundwater rights are not quantified and are separate from surface rights, even though their use can deplete surface water sources. There are also differences in how water districts manage surface water rights, limiting the ability of land owners in their districts to trade or sell their rights.

California's water rights can be improved

The drought has caused many to question the complexity and 'fairness' of California's current water system. Junior surface water right deliveries were severely curtailed in 2014 and 2015, and deliveries to senior rights holders were curtailed in 2015, the first time since the severe drought in 1976/77. The California State Water Resources Control Board (SWRCB) issued non-compliance orders, to which some senior rights holders asserted they also had riparian rights to the same water. Some senior rights holders are litigating the authority of the SWRCB. Municipal water users were obliged to reduce their water by the governor's emergency order early in 2015, though many cities have sufficient water or could buy needed water. Water has been diverted from environmental uses to cities and farms, and there has been dispute and confusion about the management of water for ecosystems during the drought, adding to the uncertainty for ag users.

Water marketing has increasingly enabled water rights holders to voluntarily re-allocate water in order to reduce the economic and environmental costs of shortages, especially during droughts. Such trading requires oversight to ensure that it does not harm other water users or the environment. But California's trading rules are fragmented and inconsistent. There are also opportunities to clarify issues, such as: how much water can be traded when land is fallowed? Can local government restrict water sales? Do land owners in water districts have the right to trade outside the district? And can short-term trades be streamlined, in comparison to long-term or permanent trades?

The Public Policy Institute of California's (PPIC) Water Policy Center suggested the following water right and water right administration reforms in its 2015 article 'Allocating California's Water: Directions for Reform'.

"Suggested reforms:

- "Bring all surface water rights under the State Water Board's permitting system. These changes would not alter the seniority of water rights, but merely add certainty and efficiency by bringing all rights under a common administrative system.

- "Require surface right-holders to choose between riparian and appropriative rights. This would not change the amount of water these landowners could use, but would prevent them from frustrating the administrative system by toggling between rights.

- "Quantify groundwater rights in priority basins. Under the Sustainable Groundwater Management Act of 2014, local pumpers must now develop plans to manage groundwater levels and prevent harm to surface water uses. Local agencies should assign pumping rights as part of this process to facilitate trades within basins—a way to lower costs. This would also increase incentives to invest in groundwater recharge—an essential tool for augmenting drought storage.

- "Develop an authoritative water accounting system. Key state agencies should develop a common water accounting framework. Water accounting information should be made publicly available in the interests of transparency and efficient management.

- "Assign an environmental water budget for each river system. The state should adopt a process to develop watershed-based environmental flows, combining a state mandate and local authority to flesh out details. The water board should assign interim environmental water budgets on different river and stream systems, based on applicable environmental laws. During droughts, certain environmental uses would have top priority—along with protections for public health and safety. Defining these environmental water budgets as water rights, rather than a regulatory baseline, would facilitate more flexible environmental water management.

- "Encourage environmental water trading. Dedicated funding is needed to enable the state or other entities to purchase some environmental water. The review process should be streamlined for temporary acquisitions of water for the environment.

- "Require water users to pay into an ecosystem fund when they benefit from a relaxation in environmental water standards. This would create appropriate incentives for water users, while providing funds that can help mitigate the loss of water for the environment.

- "Streamline regional water trading. Flexibility can be improved by consolidating permitting so that local agencies in the same region no longer need multiple layers of review by multiple agencies each time they want to share water.

- "Preauthorise some water transfers and expedite reviews. Some types of transfers, such as those beneath a specific size threshold, should be preauthorised because they are unlikely to cause unreasonable harm. Both the state and federal governments should streamline reviews for temporary transfers.

- "Encourage drought storage. The California Water Code should be amended to define storage (both above and below ground) as an allowed use of water (in legal terms, a

'beneficial use'), as long as it would serve a demonstrated public purpose such as recharging groundwater basins. The water board should also expedite granting water rights to capture excess flood flows.

- "Improve information about trading opportunities. A water transfer clearinghouse should be developed to make information available about transactions and trading opportunities."

Despite challenges, California ag will continue to grow

While the above suggestions by the PPIC are not an overhaul, they will still present some uncertainties during their possible implementation. Ag water users may still lose some water entitlements to environmental uses—especially during droughts—but they could be compensated for such takings, rather than reallocating ag's entitlement by legislation or judicial decree as in the past, with no compensation. More efficient water marketing will provide greater incentive for investment in water resources and management, but higher-valued water will make it less affordable for some ag producers, especially smaller farmers. Junior rights holders will continue to bear the largest portion of the cost for incremental water supplies during droughts. Groundwater users—currently dependent on depleting aquifers, with no access to surface water for recharge purposes—will lose a portion of their entitlement. Third-party beneficiaries of current water allocations may suffer as water is reallocated to areas of higher-value use. This would include local vendors, ag service providers, ag and food processors, government agencies and lenders. Yet these reforms will enhance further investments in the state's water systems, which benefits agriculture as a whole—making California even more competitive, and providing higher-valued food domestically and abroad.

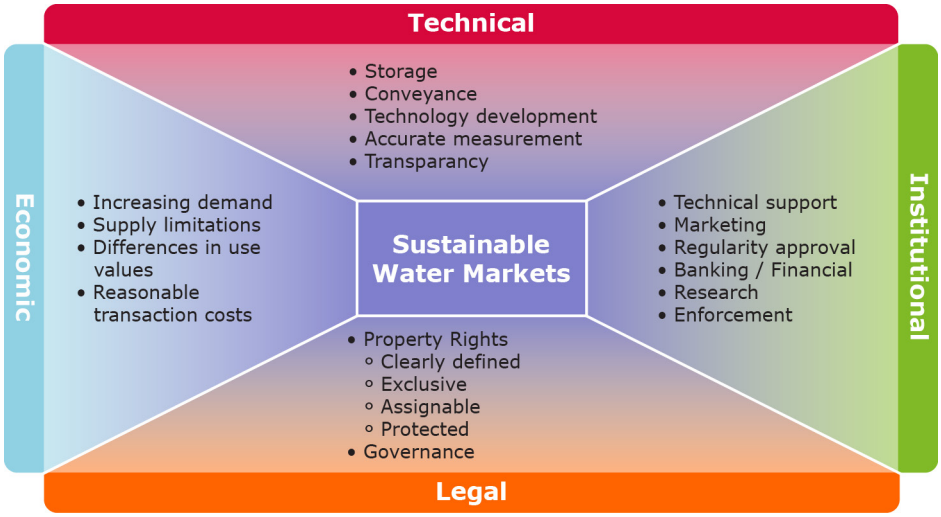
Water markets are a means to economically efficient allocations

Once basic water needs are met, additional water is not necessarily a basic human right, and there are other goods and services for which a person would give up additional water. This point implies the need for some trading/market mechanism for the quantity of water above that considered for adequate household consumption and sanitation. After all, beyond its use for basic survival, water is largely a productive input: a means of production. Even in its natural state—or its use in the environmental sustainability of ecosystems—water is but one contributing factor in producing a broader good. Its contribution can (and should) be assigned some monetary value, so that those uses (or non-use) can be compared to other uses in some measurable way. Markets—as efficient price discovery mechanisms—assign value. But markets alone don't adequately assign a value to unintended costs and benefits that can accrue to third parties. These so-called 'externalities' can be of particular consequence in the case of water, as it is a resource that impacts most everything and everyone in some way. Hence, while water markets would encourage more economically efficient allocations and investment, government intervention, of some type, is likely needed as a control for externalities.

Effective markets rely on convergence of complex factors

According to research conducted by Kaiser and Phillips for the Natural Resources Journal: "Water markets develop when a combination of economic, legal, institutional and technical factors converge so that buyers can obtain a more certain, consistent and predictable water supply relative to other options and sellers realise greater net benefits by transferring the water than by keeping it in an existing use." Economic forces must exist which make parties willing and able to trade. Legally assigned, clearly defined, exclusive and assignable property rights to water must be present, while legal authority and oversight to protect human rights and control for externalities is also critical. Institutional forces must be in place that provide effective enforcement of property rights, promote and stand behind the market system, provide technical support, provide needed capital and provide transparent flow of information. Additionally, there must be institutional capability in accurately estimating all costs, benefits and risks. Technical factors must include accurate physical measurement, storage and conveyance systems. These economic, legal, institutional and technical factors are not independent of one another—and each relies on some aspect of the other (*see Figure 6*).

Figure 6: A TILE for effective water markets—technical, institutional, legal and economic



Source: Natural Resources Journal, 1998; Rabobank, 2016

The right economic conditions

Sustainable markets rely on having many willing participants on both sides of the market (buyers and sellers) who have the means to participate. In the case of water, the economic forces which would ultimately lead to market participation are: 1) increasing water demand across multiple sectors, driven by population growth, urbanisation and environmental needs; 2) limited availability of alternative supplies; 3) differences in use values; and 4) reasonable transaction costs (driven partially by access to information).

Legal and institutional forces must support property rights

Legal and institutional forces are often difficult to uncouple, as legal authority and enforcement rely heavily on institutional integrity. The key legal principal necessary for a sustainable water market is that of legally assigned, clearly defined, exclusive and assignable property rights. The issue is that water, in its natural state, often doesn't have clear property rights or clearly defined boundaries. This issue can lead to non-excludability, where people cannot be prevented from using water. In this case, as the world has witnessed, water is overused and depleted. Countries, regions and communities have invested in infrastructure and developed policies, which allow for some enforcement of excludability. In other words, not everybody has legal access to all of the water all of the time, and specific water rights have been defined. However, the types of rights, who holds the rights and methods of right allocation vary greatly around the globe. As challenging as water right allocation is, it is a critical component in developing efficient markets.

The legal establishment of property rights is meaningless, unless robust enforcing institutions also exist, i.e. uncorrupted and effective judicial and law enforcement bodies. Promotion, acceptance and, ultimately, broad market participation rely on the cooperation of respected private and public institutions that will provide support. Public sector governance bodies, who ultimately have regulatory approval, must rely on (and garner) representation, cooperation and information from all sectors affected. A credible and robust financial/banking system will be required to promote and allow investment—especially from the private sector—in infrastructure and technology.

Measurement and transparency all the way

An effectively functioning water market system also requires accurate measurement and effective management across competing uses. Measurement includes not only the physical resource itself (i.e. flow data), but also economic measurement (valuation). Measurement requires estimation of all (including externalities) costs, benefits and risks. Accurate physical measurement requires not only institutional support, but continued advancements in technology (a technical factor). Accurate economic valuation of externalities will rely heavily on analysis by institutions of higher education.

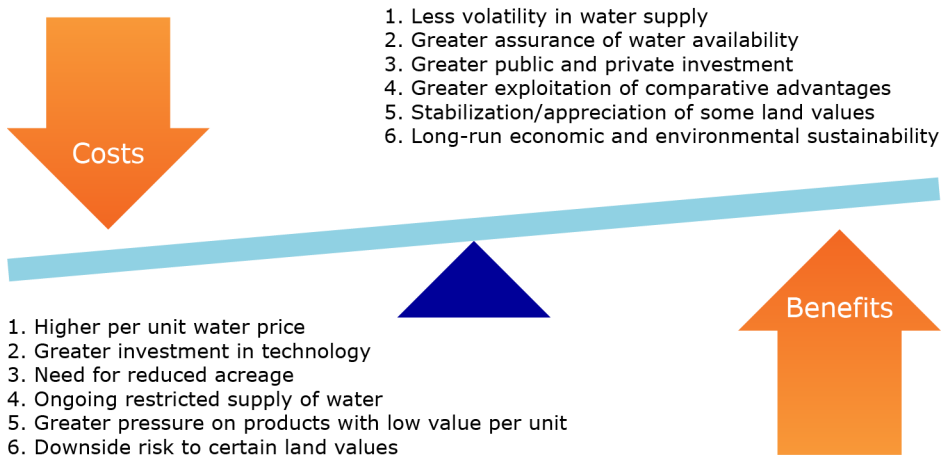
Even with accurate and timely measurement of water resources, costs, benefits and risks, markets cannot function effectively unless all relevant information is shared with all potential participants in a timely and cost-effective manner. While information will never be perfect in the real world, information flow and full transparency are necessary for the long-term sustainability of water markets.

Water superhighway

Technical market sustainability will also rely heavily on proper storage and conveyance systems (physical infrastructure), including the ability to capture usable water. Additionally, groundwater and its management can be an effective means of water storage. Water transfers can only be accomplished when water is in a usable and transferable state, and a conveyance system exists that allows for minimal water loss and reasonable 'shipping' costs. The ability of a conveyance system to efficiently deliver water to all geographic market regions increases potential participation by physically expanding the potential number of buyers and sellers that can be reached.

Long-run market benefits to agri producers outweigh costs. The costs and benefits of water market implementation will accrue differently to ag producers. They are dependent on many factors, including type of product produced, geographic location, current rights structure, water market structure, along with other region- and firm-specific factors. However, some potential costs and benefits are most likely to occur to a degree (*see Figure 7)*.

Figure 7: Not every agri producer wins, but overall benefits to agriculture outweigh costs



Source: Rabobank, 2016

Summary: one size does not fit all

Against the backdrop of not meeting people's basic water needs today, the global population is expected to increase by 25 percent by 2050. Coupled with urbanisation and rising incomes, global demand for food is expected to increase by 60 percent. Water demand for manufacturing is expected to rise by 400 percent between 2000 and 2050, and rising global demand for energy will further pressure water resources. Lastly, the importance of water to maintain ecosystems is now globally recognised. All said, the UN expects global water demand to increase by 55 percent by 2050, and by 2030, the world is expected to have a 40 percent global water deficit, based on the UN's business-as-usual (BAU) scenario. Given this general global water challenge, the industry of agriculture is in a paradoxical situation—because it is both the vehicle required to feed a growing world, while, at the same time, being the world's largest user of developed water.

In its 2006 Human Development Report, the UN stated: "Water scarcity is both a natural and a human-made phenomenon. There is enough freshwater on the planet for 7 billion people, but it is distributed unevenly, and too much of it is wasted, polluted and unsustainably managed." All too often, wastewater goes untreated, wells are overdrawn, and water rights are overallocated.

The development of effective water markets requires the convergence and coordination of technical, institutional, legal and economic forces, in a comprehensive approach that meets the needs of society. However, different countries/regions of the world are at different stages of economic development, have differing economic and legal systems, have extremely divergent institutional characteristics and possess differing technical characteristics in terms of current water system capabilities. The development of water markets in specific regions of the world will therefore evolve differently, at different paces, and take on nuances that are specific to each region's characteristics. As markets are implemented/expanded, each area's ag producers potentially face slightly different costs and benefits—but, in general, markets will increase the overall net benefit to society, while decreasing risk for the ag sector as a whole.

Regardless of region or historical water availability, droughts are inevitable. More countries and regional agricultural areas must effectively manage their respective water resources. Countries will continue to find it necessary to change their water strategies due to scarcity. Globally, governance is needed to develop systems which are not only sustainable, but also replenish current deficits caused by years of overuse. International discussions will need to happen to properly allocate water where it is needed. Growing populations will inevitably demand more food and more water. Otherwise, the current lack of investment—both from public and private sectors—will hinder our collective ability to develop storage and conveyance systems adequate for impending growth. The direct involvement of food and agri suppliers and other leaders will be crucial to the development of water markets in a way which will protect the long-run economic sustainability of the agriculture industry.