Impending Scarcity Conditions:
Water resource management reform in the Egyptian irrigation sector

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Between 1965 and 1995, the world experienced a 73% increase in net irrigated lands, from 150 million to 260 million hectares (ha).[1] Most of the newly irrigated area was located in the developing world alongside the overwhelming majority of the world's population growth. Many of these developing nations were relatively young and facing the challenges of the first years of autonomy. The expansion and installation of irrigation systems during this time represented a critical improvement in infrastructure and a necessary step on the path to national self-sufficiency.

The exponential population growth in these countries emphasizes the importance of irrigation systems in meeting the increasing demand for food. In 1997, the World Bank estimated that its irrigation projects had brought improved food security and a higher standard of living to 46 million farming families in the developing world.[2] With a population of 76 million, Egypt has been a major beneficiary of the worldwide boom in irrigation. Rapid population growth, at a rate of two percent per year, has pressured the government to respond to the increasing demand for basic agricultural products.[3] At this rate, in thirty years the Egyptian population will double, just as it did between the mid-1970s and 2004.

In contrast to overpopulated nations like India or Indonesia, which are more densely populated per square kilometer, Egypt is positively under populated. It has no shortage of land, but suffers from an inadequate water supply. Arable land accounts for only four percent of the total land area in Egypt, most of which is found along the Nile River and Delta. Ninety-six percent of the Egyptian population lives in this area, making it one of the most densely populated regions in the world. The Egyptian government, aware of the problems overpopulation presents to its society, has embarked on ambitious desert reclamation projects to create an additional 600,000 ha of arable land by 2017.[4]

Such proposals are indeed incredibly ambitious given the intense water demands they impose on an already stressed freshwater resource. Development costs are also significant, given that the Egyptian government cannot provide the majority of the funding. Before overextending its water supply through these projects, Egypt must reform its irrigation sector and improve water efficiency.

Egypt and the Aswan High Dam

For thousands of years, Egyptian society had been vulnerable to fluctuations in the Nile. The completion of the Aswan High Dam in the 1970s virtually eliminated that vulnerability. The dam and resultant reservoir behind it, Lake Nasser, mitigated the seasonal and annual fluctuations in the river. Lake Nasser has a water capacity of 162 billion cubic meters, equivalent to three times the annual flow of Nile waters to Egypt. Through the opening and closing of spillways in the dam itself, during times of drought or flood, Egypt has the ability to more or less control the water level of the Nile downstream from Aswan.

The sign at the visitor's center atop the dam reads "The High Dam Project is considered the Egyptian challenge against the silent nature," and it is. It fundamentally changed irrigation in Egypt. Prior to the construction of the Aswan High Dam, much of the land in Egypt was irrigated via "basin irrigation." Basin irrigation in the Nile River Valley relied on the oscillating flow of the river and the summer surge from the Blue Nile and Atbara Rivers, when daily discharge can sometimes reach a total of 700 million cubic meters.[5] At most, basin irrigation yielded one harvest per year. After the summer flood, farmers would sow the seeds between October and December, harvest the crops in April or May, and then let the land lay fallow in anticipation of the flooding in August and September. The dam greatly reduced the amplitude of fluctuations between the summer surges and the spring droughts, allowing for "perennial irrigation." Perennial irrigation means that irrigation waters are available at any time of year, through the opening and closing of spillways in the High Dam. This allows for two to three growing seasons per year, and for the expansion of irrigation networks.[6] Egyptian farmers achieved higher standards of living as annual crop yields spiked and suitable growing areas increased. Controlling the flow of the river also allocated the annual Nile River flow more efficiently. Prior to the creation of the dam, a considerable amount of water would run straight to the Mediterranean during times of flood, and during times of drought the water stress level would prohibit any agriculture.

While the dam played a major role in the transformation and modernization of Egypt, it has been continually criticized for its social and ecological effects. The Aswan High Dam collects sediment as water moves through its spillways to control the flow of the Nile This nutrient-rich sediment had fertilized the banks of the river for millennia. The silting that occurs behind the dam necessitates the use of chemical fertilizers downstream and causes the growth of aquatic weeds both in Lake Nasser and in downstream waterways. The stagnant waters of the reservoir also create favorable conditions for water-born illnesses such as malaria and bilharzias (or schistosomiasis). Opponents of the dam also criticize it for causing evaporation and absorption losses in the reservoir, the resettlement of Nubian peoples, degradation of the river course, and shore erosion in the Nile Delta.

Egyptian public opinion has consistently maintained that the benefits of the dam outweigh the costs. The dam represents, to Egyptians, "their dignity, insistence, will, and determination to their benefits and interests."[7] Mahmoud Abu-Zeid, the current Minister of Water Resources and Irrigation, aptly summarizes the chief benefits of the dam: cheap, "clean" creation of electricity, improved irrigation systems, security from flood or drought, and the general increase in the standard of living for the average Egyptian. However, the Aswan High Dam also generates a number of complex externalities and spillovers. These cost-generating externalities include management of the hydroelectric infrastructure, periodic hydrological surveying of the reservoir, social loss in the resettlement of displaced peoples, measures to correct river course degradation and shore erosion, public health costs in the research and treatment of endemic disease, and the operation and management of an irrigation system that had more than 150,000 km of main, secondary, and tertiary canals in 1997.[8]

Water Use in Egypt

The 1959 *Agreement for the Full Utilizations of Nile Waters* with the Sudan gives Egypt an average of 55.5 billion cubic meters per year at Aswan. Due to the control the dam exerts over the river, Egypt enjoys efficient exploitation of the water it receives. The reuse of drainage and runoff from irrigated lands and recycled waste waters supplement the 55.5 billion cubic meters from the Nile by about eight billion cubic meters, bringing the total water supply in the country to 63.7 billion cubic meters, according to a 1996 calculation by the Egyptian Ministry of Hydraulic Resources and Public Works.[9] About 80% (49.7 billion cubic meters) of that supply is expended on agriculture, which accounts for virtually all recycled water in the system. The remaining 20% is principally divided between industrial and urban uses.

Egypt's current annual water use is estimated at two billion cubic meters less than its annual water supply.[10] Economically speaking, this fact is telling of the way Egypt views its water resources. The annual demand for water in Egypt is below water supplied, ostensibly generating a water surplus. Thus, at the macroeconomic level, Egypt does not consider water supply a limiting condition in regulating demand. There is, however, a disadvantage to seeing water use from a free market economic perspective: the government does not charge farmers for the delivery, use, and eventual drainage of irrigation water. As such, the resultant price of water does not accurately reflect the real costs of water to society as a scarce resource.

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Part of this problem can be attributed to ideology. Water is viewed as a fundamental human right, and many Egyptians believe it is the responsibility of the government to supply clean water to its citizens. Any attempt to increase the price of water to reflect its actual costs, or to remove subsidies on irrigation water and systems, would be met with opposition. Two-thirds of the Egyptian population engages in agriculture as their primary occupation, with many working on plots of land no larger than 0.5 to 0.8 ha.[11] These small scale farmers in rural Egypt do not enjoy a high standard of living and in order to prevent mass migration to Egypt's already overcrowded cities, the Egyptian government must ensure that the economic incentive to maintain a rural farming lifestyle outweighs the opportunity cost of relocating to an urban center.

Despite two billion cubic meters of water remaining unused ever year, water shortages are common due to asymmetric distribution, constraints on water conveyance capacity, and systemic inefficiencies.[12] The lack of a pricing regime for irrigation water exacerbates these problems. Given a price for water, the rational farmer will consume an amount of water that maximizes his personal net benefit. Unless the cost to the farmer represents the real cost of water to society, the level of consumption that maximizes the net personal benefit to the farmer will be incongruous to the level of consumption that maximizes the net social benefit. As the farm-level cost of irrigation water in Egypt is currently equal to the cost of pumping the water from the nearby tertiary canal, the farmer is motivated to consume a larger amount of water than what is socially optimal. Stated practically, cheap irrigation provides no incentive for farmers to use the water efficiently. A pricing regime would increase the price of water, thereby eliminating this problem. Other nations facing water scarcity conditions have opted for the privatization of water resource management and distribution, allowing the market to reverse water stress and increase efficiency. Privatization has met mixed levels of success in these nations, and Egypt has yet to seriously explore this option in its irrigation sector.

New Development Projects

Future sources of pressure on the Egyptian water supply, principally the country's projected population growth over the next thirty years, require immediate attention. Reforms must be implemented to increase water use efficiency. By 2017, the Egyptian government hopes to complete ambitious development projects to reclaim land in the north, east of the Nile Delta and on the northern part of the Sinai Peninsula, and in the south, near Lake Nasser along the Toshka Depression. The first project, the Northern Sinai Agricultural Development Project (NSADP) will irrigate some 250,000 ha of land while the second, the South Valley Development Project (SVDP), will irrigate 336,000 ha. The two projects reflect the government's effort to alleviate the overpopulation of urban centers and create jobs for the unemployed.[13]

These projects carry taxing hydrological and financial demands. If successful, the projects will increase Egypt's arable land by 20 percent. The NSADP will need an estimated 1.7 billion cubic meters of water annually, while the SVDP requires an estimated five billion cubic meters per annum. Water will come from the Nile, with 50% of the water for the NSADP coming from drainage and runoff in the Nile River Valley and Delta, and all of the water for the SVDP being pumped directly from Lake Nasser via a hydroelectrically powered pumping station.[14]

NSADP is to be funded primarily through international development institutions such as the World Bank, as the newly irrigated lands in this region would be used mainly for farming subsistence crops typically cultivated by the majority of rural Egyptians (i.e. wheat, rice, sugarcane, etc.). To this end, the World Bank issued Egypt a loan of $15 million expressly for land reclamation and settlement purposes in the East Delta adjacent to Sinai.[15] The SVDP has been funded almost entirely by private sources. The irrigated land in the south is intended primarily for the farming of horticultural crops, which can be traded in European markets and augment job creation. The financiers in this case, the majority of them Saudi, are capitalizing on the flexible Egyptian growing season, which allows them to penetrate the European market weeks ahead of competitors in other agricultural economies.[16]

The money for the basic irrigation system does not take into account peripheral costs of agricultural and social infrastructure developments necessary to encourage mass relocation. The complete cost per hectare of land reclaimed for all the necessary infrastructure improvements is estimated to be upwards of $25,000 per hectare, with the estimate for the entire project hovering between $60 billion and $90 billion over a span of 20 to 30 years[17]. Considering that the project involves the creation of 336,000 ha of habitable, arable terrain in the desert, complete with the necessary infrastructure development, such figures are reasonable. Investors are not in short supply despite the water scarcity in the country.

At 6.7 billion cubic meters, the total per annum water requirements of the two water reclamation projects exceed the total flow of Nile waters to Egypt by ten percent. If nothing is done to decrease the demand for water, Egypt may soon face a perennial water shortage. Unless improvements are made in the efficient allocation of water, especially in the agricultural sector, these ambitious development projects will severely stress Egypt's water resources.

The Need for a Pricing Regime for Irrigation Waters

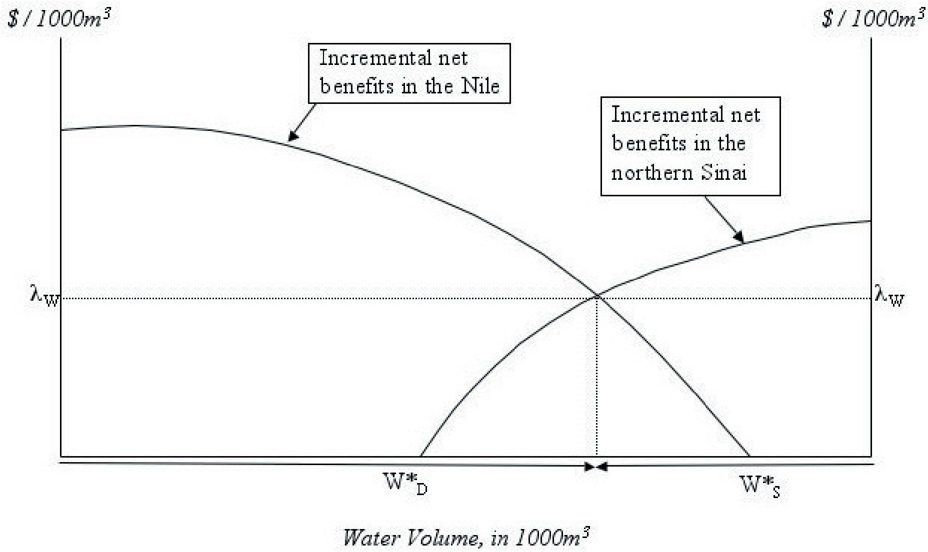
Under a socially optimal water allocation model drafted by Wichelns, where water is allocated at a level where the incremental costs of water per region are equal, it is currently more beneficial for society as a whole to allocate water to the Nile River Valley and Nile Delta rather than to the two development regions.[18] A more concrete and simplified example of Wichelns' net social benefit maximization model is seen in Figure 1.

The left Y-axis represents the incremental cost of water in the Nile Delta, the right Y-axis represents the incremental cost of water in the northern Sinai region, and the X-axis represents the respective shares of the total water supply. At the socially optimal equilibrium point, where the marginal benefit curves for each region intersect, the socially optimal incremental cost of water, λ_w, is the same in both regions. Where this occurs, the Nile

Delta's water share (W_D) constitutes the majority water share in the model.

Intuitively, this makes sense. Given that the area under the incremental net benefit curve, the differential of the curve's equation, represents total net benefits, at every single value for λ along the Y-axes total net benefits in the Nile Delta exceed total net benefits in the northern Sinai region. In a socially optimal allocation model, which carries absolutely no outside bias towards a region, water would be allocated to the area where more benefit results from its application. Of course this is a simplified version of the model, but in Wichelns' four-region model (Toshka, Sinai, Delta, and Valley), he proves unambiguously that under the current water distribution regime, it is economically more prudent to allocate water first to the existing agricultural regions.

FIGURE 1[19]



If the Egyptian government acted rationally, according to the model, land reclamation projects would be delayed until the point where the incremental cost of water in the Nile Valley and Delta increased sufficiently to slide the socially optimal equilibrium point towards the left Y-axis. Unfortunately, the political and social value of these projects transcends the basic economic value. These ambitious undertakings are not only valuable from the standpoint of relieving an overcrowded region of the country, but also as a matter of national pride. Combined, the two projects represent quite possibly the boldest land reclamation plan in history. Were Egypt to successfully complete them, it would fundamentally change the landscape of the country.

This presents Egypt with two options: to continue as it has, in the hope that the water scarcity condition will not breach a critical level, or to implement a pricing regime in the distribution of irrigation waters that would effectively increase the incremental cost of water in the Nile Valley and Delta. The latter option is better in that it would improve water use efficiency, as farmers will be less careless at higher water prices. Furthermore, more water would be diverted to the development projects in the socially optimal allocation model, and it would generate revenue for continued operation and maintenance of the existing irrigation infrastructure and creation of new infrastructure.

Pricing irrigation water at the socially optimal price level can result in price incongruency. The individual rural Egyptian farmer, being a rational economic actor, will always choose the input combinations that minimize cost.[20] Under the current Egyptian distribution regime for irrigation water, the only cost to farmers is the cost of diverting water from the irrigation canal to their farm. This is dramatically lower than the full social cost of water as exhibited in Figure 2.

The bottom horizontal line in the graph represents the cost per cubic meter of diverting water. At that level, the individual farmer uses water at the level W_F. The middle horizontal line represents the cost of diverting water as well as the cost of water delivery in the irrigation system. As the price paid for water by the farmer increases, the farmer slides left along the farm-level incremental revenue curve, thereby reducing the quantity of water demanded. The top line represents the cost of diverting water, the cost of water delivery, and the shadow price, or opportunity cost of alternative water use. The corresponding quantity of water demanded, W^*_F, represents the truly optimal farm-level allocation of water. In terms of revenue creation for the state, pricing water at the cost of diversion generates no revenue. Pricing at a level which includes the cost of water delivery generates revenue equal to the areas of A + D, and the true social price of water would generate revenue for the state equivalent to the area equal to A + X, clearly the best case for the government in terms of revenue creation.

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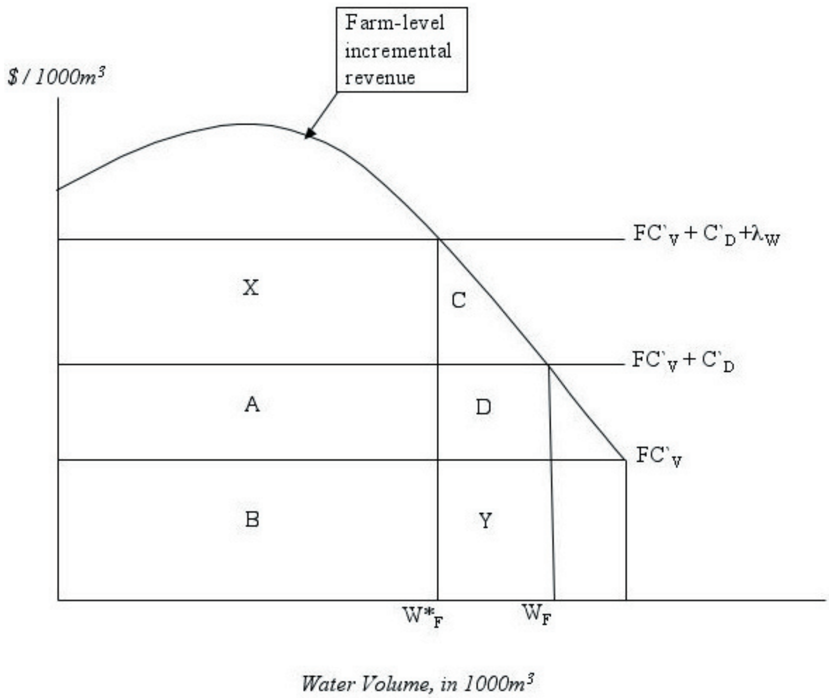
FIGURE 2[21]



POLICY FOR PRICE REGIMES

Given the asymmetry between the objectives of the state and the objectives of the individual farmer, the state has a vested interest in reflecting the real cost of irrigation water in the prices received by the farmers at the lowest levels. How would the Egyptian government go about implementing an increased cost for irrigation water? There are two primary pricing policy options.

The first and more direct option is volumetric pricing. Volumetric pricing involves having the farmer pay per unit of water delivered to his land. This is akin to the pricing of water in most of the world's cities and in the irrigation systems of developed regions such as the United States or the European Union. The farmer still pays the water diversion cost himself (usually the cost of operating an electric or fossil fuel water pump) but also pays a per cubic meter cost to the Egyptian Ministry of Water Resources and Irrigation, which reflects the implicit costs of the operation and maintenance of the conveyance and drainage systems. A 1993 World Bank study estimated the implicit costs at $0.0088 per cubic meter, generating government revenue of $33 per hectare for less water intensive crops like wheat, and revenues of

$184.38 per hectare for more water intensive crops like rice.[22]

Although volumetric water pricing is the preferable method of implementation, it requires a sophisticated monitoring infrastructure that is lacking in rural areas. For these areas, crop-specific land assessment offers a more indirect approach to increasing the cost of irrigation water. Based on the per hectare cost of irrigation water for the different crops, (i.e. $33 for wheat and $184.38 for rice) the farmer would pay a flat sum in conjunction with his land tax, the value of which would be contingent on the specific crop being harvested. Under this pricing regime, farmers would be more reluctant to farm water intensive crops like rice and sugarcane, thereby conserving water. A downside of this approach is that it fails to directly influence the level of water use. For example a wheat farmer may still grossly abuse the water supply and incur no more penalty than the $33 per hectare he is already paying. It still is a solution that could be easily and cheaply implemented, and could be an effective supplement in regions where volumetric pricing is unfeasible.[23]

Technological Improvements

As mentioned above, the implementation of volumetric water pricing requires a more sophisticated infrastructure for monitoring water use than Egypt currently has. This emphasizes the importance of impending technological improvements in the irrigation infrastructure. The primary and secondary canals face rampant aquatic weed growth, which not only usurps water supply, but also restricts flow, damages pumps, and plays host to endemic water-born diseases such as bilharzias and malaria. Other maintenance issues include problems with conveyance such as the lining of canals to prevent seepage, fixing leaks, and general upkeep of pumping stations.

Broadly, technological improvements should focus on developing the water monitoring infrastructure for secondary and tertiary canals. In 1992, as part of the Egyptian Ministry of Public Works and Water Resources' Irrigation Systems Management Project, Egypt commissioned a civil engineering firm to improve the monitoring infrastructure at a price of $23 million.[24] The idea was to install a system-wide communications system that relayed flow and water-quality data in real time to the Ministry's headquarters. At its installation, the system was linked only to the main canals and pumping stations coming off the Nile River. For the accurate local measures of water use necessary for the successful implementation of volumetric pricing, such a monitoring infrastructure would have to spread to and regulate the secondary, tertiary, and quaternary canals as thoroughly as possible, financial and logistical limitations notwithstanding.

Technological developments at the farm-level would focus on the improvement of irrigation methods. The default irrigation scheme at the farm-level is the continuous flow irrigation scheme. Under this scheme water is admitted to the furrow for a period of time, usually several hours, and then left to soak into the ground. Because the earth has limited capacity to retain this water, continuous flow irrigation often leads to problems with excess runoff and drainage, deep percolation of the soil, and non-uniform wetting of the land. There are more efficient methods, which could be widely implemented on Egyptian farms.

Capital intensive methods such as drip or trickle irrigation are not viable options for rural Egyptian farmers who farm smaller plots of land.[25] A more realistic irrigation solution utilizes the surge method. Water is applied to the furrow intermittently and at a high velocity, causing a sudden surge for a short period of time. After the surge, the water is left in the furrow to infiltrate the soil. By the next surge most of the water is fully absorbed, resulting in decreased runoff and a more uniform distribution. Surge flow irrigation, when operated manually, requires no capital investment on the part of the individual farmer. An automated system requires only the installation of a surge valve and is lower in capital intensity than a drip irrigation system. A study conducted by Ismail et al in 2004 determined that surge flow irrigation, if implemented in Egypt, could save 15-35% more water than the conventional continuous flow irrigation.[26]

Cooperative Current in the Implementation of Water Management Policy

The Egyptian Ministry of Water Resources and Irrigation (MWRI) employs 80,000 people and is most effective at its higher level areas of responsibility.[27] However with 150,000 kilometers of canals and drainage ducts filling the Egyptian landscape, the organization is limited in its capacity to act. Effective enforcement and implementation of price regimes and technological reform at the lower level canals in the irrigation system is a decidedly difficult task.

In a 2003 paper on the institutional reform of the irrigation sector in Egypt, a MWRI official, Hesham Kandil, outlined the need for human resource development and reform in the irrigation water sector. Kandil sees the increased participation and involvement of the stakeholder at the lowest level as imperative to a working, efficient irrigation system in Egypt.[28] The effective decentralization and transfer of decision-making authority on the local scale to regional authorities and stakeholders is a step in the right direction towards meaningful improvements in the irrigation sector.

In the current regime, the MWRI handles all distribution and drainage until the very lowest unit, the farmer, who is responsible only for diverting irrigation water onto his land and emptying runoff and drainage water into drainage ditches. Kandil outlines two separate options for reform in this system. The first involves the withdrawal of the MWRI from the tertiary canal level and the establishment of water user associations at the local level responsible for operation and management of the waterways. The second option is based on the Dutch model of district water boards, which manage waterways from the secondary canal level down, and have authority over subsidiary water user associations.

The vision of water user associations playing a large role in the Egyptian irrigation sector was first explored in 1987 with the inception of the Irrigation Improvement Project (IIP).[30] The IIP, currently funded by an $80 million World Bank loan[31], was established to improve the efficiency of water use at the tertiary and quaternary levels of the irrigation sector. The water user associations have been effective in ameliorating conflict between farmers, maintaining a high level of stakeholder participation, reducing "water theft" in regions susceptible to it, and in inspiring a spirit of cooperation in the management of a common resource.[32] However these associations still have a long way to go. Legally, they are such a new entity that the limits of their jurisdiction and authority are only vaguely outlined. The irrigation infrastructure is still government property, and the MWRI requires that quality, equity, and environmental standards are met by water user associations and water boards through coercive policy means.

Egypt is a country at a crossroads. Demand for water is poised to grow, creating an impending scarcity condition.

Conclusion

In a country facing problems with water scarcity and population growth, it is troubling that World Bank loans for irrigation and water issues are trumped by nearly $50 million in the World Bank loans for the development of Cairo International Airport.[33] Egypt is a country at a crossroads. Demand for water is poised to grow, creating an impending scarcity condition. By 2025 the government is slated to complete the massive land reclamation projects it is undertaking, yet the increase in arable land area will foster unprecedented stress on Egypt's lone source of fresh water, the Nile River. To prosper in the 21st century, Egypt must reform its irrigation policies to ensure efficient and equitable distribution and use of the scarce water supply. The adoption of a cohesive, viable pricing regime and the implementation of more efficient irrigation technologies are critical steps toward realizing these goals.

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