

**Growing more food with less water: How can revitalizing Asia's
irrigation help?**

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Abstract

Irrigation has always played a central role in the agrarian economy of Asia, from supporting famed hydraulic civilizations in the ancient past to spearheading Green Revolution in the 1960s and 1970s,. Asia accounts for 70% of the world's irrigated area and is home to some of the oldest and largest irrigation schemes. While these irrigation schemes played an important role in ensuring food security for billions of people in the past, their current state of affairs leaves much to be desired. The purpose of this paper is analyze the current trends in irrigation in Asia and suggest ways and means for revitalizing irrigation for meeting our future food needs and fuelling agricultural growth. The paper recommends a five pronged approach for revitalizing Asia's irrigation and provides region specific strategies for the same. The underlying principal of these multiple strategies is the belief that the public institutions at the heart of irrigation management in Asia need to give up comfortable rigidity and engage with individual users' needs and the demands placed by larger societal changes.

1. Introduction

How much more food would Asia need by 2050? Is there enough land and water to grow this amount of food, without inflicting irreversible damage to the environment? In this quest for more food with less water, what role can Asia's irrigation systems play? What would it take to revitalize Asia's irrigation and how best can it be done? Do different regions of Asia need to follow different strategies for revitalizing irrigation systems? If so, what could those strategies be? The purpose of the paper is to address these questions and provide a list of innovative suggestions for revitalizing Asia's irrigation.

From supporting famed hydraulic civilizations in the ancient past to spearheading Green Revolution in the 1960s and 1970s, irrigation has always played a pivotal role in the agrarian economy of Asia. Indeed, it is equally true that many ancient civilizations like that of Angkor in Southeast Asia collapsed due to failure in irrigation management. It therefore comes as no surprise that Asia accounts for the bulk of irrigated area in the world (70% of all irrigated area) and is home to some of the largest as well as oldest surface irrigation schemes. Largest, and oldest, as they may be, Asia's surface irrigation sector is also beset with a number of often intractable problems. Important among these is the consistent under-performance of irrigation schemes – most often than not, these deliver much more water than required for head end farmers and irrigate much less land than they were originally designed to do, thereby affecting the tailend farmers. This results in low land and water productivity; low returns on investments; end users (farmers) disinterest and apathy in these systems and eventual exit, if they have such an option, from these formal irrigation systems. At the heart of these problems is the low accountability of the irrigation officials to their farmer clients and this is often exacerbated by technical design problems.

The purpose of this paper is to present a menu of options that has the potential of revitalizing Asia's irrigation by gearing it towards the dual aim of poverty alleviation in poorest parts of Asia and helping in diversification and expanding livelihood options in the more dynamic parts, so that, Asia as a continent, can continue to grow more food with less water to feed an ever increasing population in face of unprecedented challenge of climate change.

1. How much more food and water by 2050?

Asia's population will reach 5 billion by 2050. How much more food would we need by then? Table 1 provides projection on future food demand for South, East and Central Asia¹.

Table 1: Food supply projections for Asia (million metric tons)

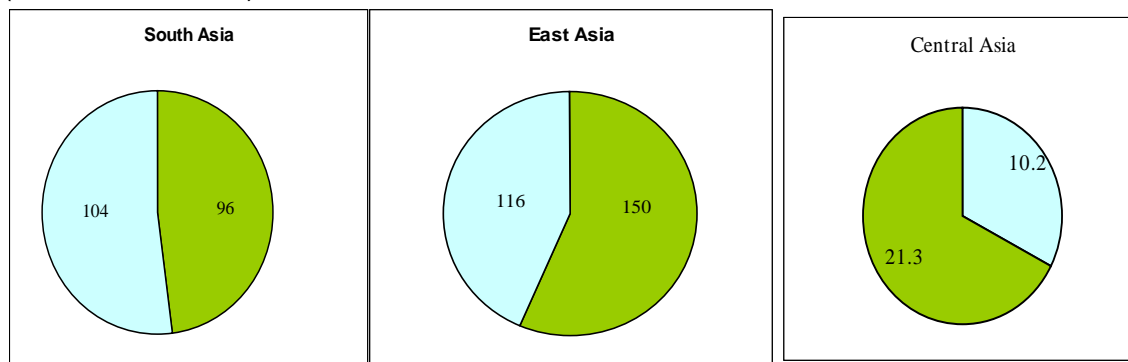
	South Asia			East Asia			Central Asia		
	2000	2050	% change	2000	2050	% change	2000	2050	% change
Wheat	96	205	114%	121	193	60%	13	26	100%
Maize	17	32	88%	184	341	85%	0.8	1.3	63%
Rice	113	202	79%	219	287	31%	0.4	1.1	175%
total cereals*	249	471	89%	529	935	77%	15	30	102%
Meat	8	32	300%	75	190	153%	1.5	3.7	147%
Milk	114	382	235%	19	60	216%	10	23	131%

Includes food, feed and other uses

Source: Fraiture 2009

As is well known, production of food, feed and fibre requires large amounts of water. On average, one kilogram of grain evapo-transpirates about 1,000 liters of water, but estimates vary from 400 to more than 5,000 liters per kilogram of grain depending on several factors including climate and cultivation practices. For South, East and Central Asia total annual crop water requirements amount to 1505, 1692 and 164 km³ respectively. A large portion of this comes directly from rainfall that infiltrates the soil to generate soil moisture, while the rest is met by irrigation withdrawn from surface and groundwater sources and delivered to farm fields. Figure 1 shows the area under rainfed and irrigated agriculture in South, East and Central Asia.

Figure 1: Irrigated and rainfed harvested area in South Asia East Asia and Central Asia (in million hectares)



Blue= irrigated; Green = rainfed;

¹ South Asia: India, Afghanistan, Bangladesh, Nepal Pakistan, Sri Lanka

East Asia: China, Indonesia, Malaysia, Myanmar, N & S Korea, Philippines, Cambodia, Laos, Viet Nam, Thailand

Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan

Without improvements in land and water productivity or major shifts in production patterns, the amount of evapo-transpiration (ET) in 2050 would increase by 70% to 90% globally depending on actual growth in population and income, and assumptions regarding the water requirements of livestock and fisheries. For South, East and Central Asia this would mean that crop ET requirements will reach 1505 km³ to 2860 km³, 1692 km³ to 3215 and 164 km³ to 312 km³ per year respectively. That is almost double the amounts needed now (Molden et al 2007). However, even with improvements in water productivity, agriculture will continue to consume a large portion of the world's developed water supply. But do we have that much water?

2. More food with less water? Outlook for 2050

Feeding 1.5 billion additional Asian people by 2050 will require water development and management decisions that address tradeoffs between food and environmental security. Four broad strategies that will help us achieve this include (Fraiture et al. 2007):

- a) Investments to increase production in rainfed agriculture;
- b) Investments in irrigated agriculture;
- c) Agricultural trade;
- d) Managing demand by reducing waste from field to fork.

Each of these strategies will affect water use, the environment, and the poor in different ways. Enhanced agricultural production from rain fed areas and higher water productivity on irrigated areas can offset the need for the development of additional water resources (Molden et al. 2007). But the potential of rainfed agriculture and the scope to improve water productivity in irrigated areas is debated (Seckler et al. 2000, Rosegrant et al. 2002). Trade can help mitigate water scarcity if water-short countries import food from water abundant countries (Hoekstra and Hung 2005). But political and economic factors may limit its scope (Fraiture et al, 2004, Wichelns 2004). Investments in irrigated agriculture will help alleviate rural poverty (Castillo et al 2007, Faures et al 2007). But irrigated area expansion may have serious consequences for the environment (Falkenmark et al 2007). Thus, there are divergent views on the pathways for the future.

In this paper, we summarize the results of the scenarios exercise done under the Comprehensive Assessment of Agricultural Management (CA) to illustrate and quantify tradeoffs in investment strategies for South, East and Central Asia (Fraiture et al 2007, Fraiture 2009). Scenario analysis conducted as part of the CA indicates that growth in water diversions to agriculture varies between 10% to 57% by 2050 for South Asia; between 16% and 70% for East Asia and between 9% and 37% for Central Asia. Increases in cropped area vary between 3% and 18% for South Asia; 10% and 34% for East Asia and 21% and 53% for Central Asia. Increases in crop water depletion are estimated between 13% and 36% for South Asia; 10% and 43% for East Asia and 20% and 55% for Central Asia. This analysis does not take into account climate change. Forecasts vary with assumptions regarding the potential of rain fed agriculture, the potential of water productivity improvement in irrigated areas and the scope of irrigated area expansion and agricultural trade. Importantly the large range of values also indicates that there are several options to consider.

It is obvious that the higher range of predicted values are impossible (for example, 57% increase in water diversions and 36% of water depletion in South Asia), and may be reached only with grave environmental consequences. Therefore, our best bet is to increase food production with minimum amount of additional water diversions. Reducing

additional water depletion would also need investments in investments in bio-technology and new seeds that can withstand water scarce conditions. In Asia, which already accounts for the world's bulk of irrigated area, this can be done through improving the performance of existing irrigation systems. These systems are plagued by a number of problems and some of the recent trends in demography, volatile food and energy markets and uncertainty associated with climate change is likely to pose new challenges. The next section summarizes some of the recent trends in Asia's irrigation sector.

2. Recent trends in Asia's irrigation

Asia is a continent in transition. Still home to the largest number of poor in the world, it is also home to two of the fastest growing economies of the world, that of China and India. While the continent is urbanizing fast and it is expected that more than 50 percent of Asia's population will live in towns and cities by 2050, agriculture will still remain the main occupation for the bulk of Asia's projected population of five billion by 2050. Just like a rapidly changing Asia, its irrigation sector is also undergoing structural changes and this will have important implications for the continents' ability to grow more food with less water diversions.

2.1 Under-performance and shrinkage of large scale surface irrigation systems

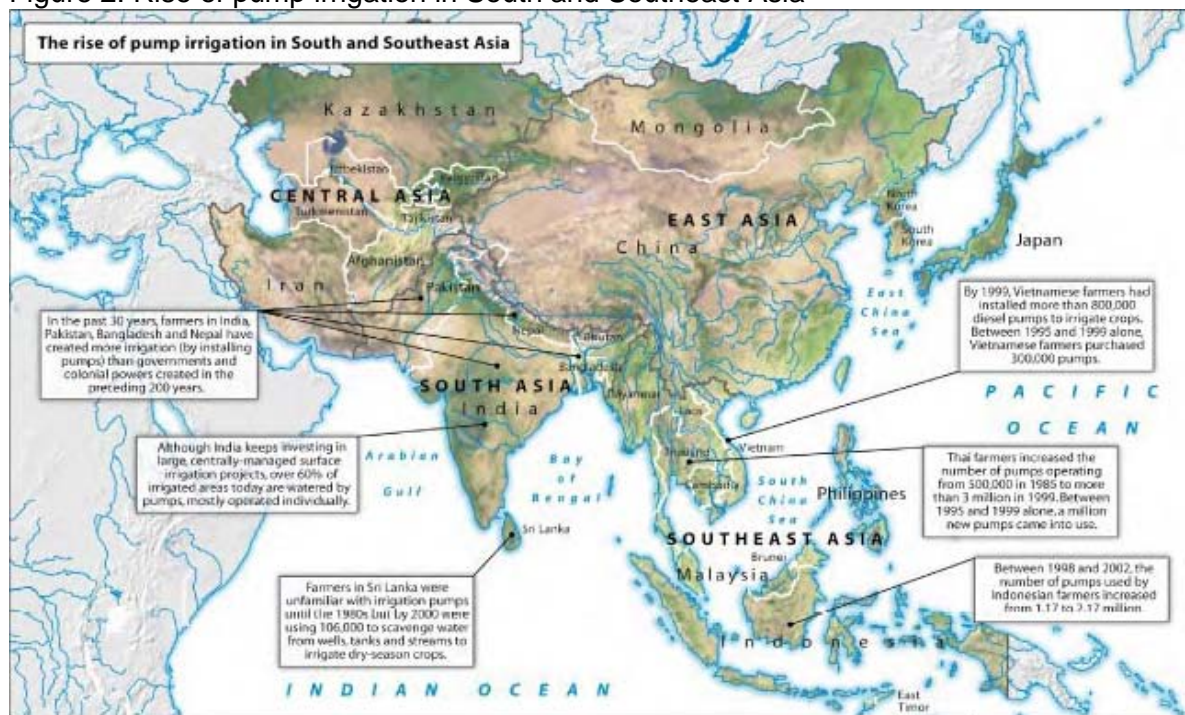
Large scale surface irrigation schemes, once dubbed by Jawaharlal Nehru as the "temples" of modern development, are on the decline not only in South Asia, but also elsewhere. For instance, after the collapse of Soviet Union, Central Asian Republics inherited large irrigation schemes, which have since then fallen into disrepair. In Southeast Asia, it is now well documented that many, if not most, large to medium scale public irrigation schemes are performing below their potential due to inappropriate design and lack of proper operation and maintenance. Much of this under-performance is related to the fact that these systems were designed around rice, which tolerates inflexible delivery of water – but now farmers want to diversify and intensify their cropping patterns to higher value crops and these irrigation systems are falling short to cater to these new demands (Johnston et al. 2009). Of all the regions in Asia, it is South Asia, where the problem of under-performance of irrigation systems has taken an epic proportion. Between 1994 and 2003, India and Pakistan together lost more than 5.5 million ha of canal irrigated area, despite, very large investment in rehabilitation of existing canals and construction of new ones. This is due to poor functioning of these systems which forces the farmers to opt out and invest in their own irrigation sources. Even otherwise, productivity (both land and water) in far too many of these large scale surface irrigation scheme all across Asia is abysmally low (Molden et al. 1998), though there are exceptions such as high performing systems in China and Turkey. There is also evidence that South East Asia—especially Malaysia, Indonesia and Thailand have interesting examples of management improvements in rice irrigation systems; and that China has experimented with alternative institutional arrangements for canal water distribution through incentivized irrigation bureaucrats and contractors (Shah et al. 2004). Even in these highly productive areas, issues of competition for water with cities, water quality and environmental degradation, and equity remain as key concerns.

2.2 Moving from centralized gravity flow systems to individual lift based irrigation

While Asia's large scale surface irrigation schemes continues to under-perform, total area under irrigation is on the rise everywhere, except in Central Asia. This is due to the

rise of individualistic groundwater based irrigation fueled by cheap pumps and often supported by government subsidies in the form of cheap electricity. This ‘water scavenging’ irrigation, as it is often called (Shah 2008) is most visible in South Asia and in drier North China plains, but is on rise even in wetter parts of Southeast Asia (Figure 2). What pump irrigation is able to do, but large scale public systems are unable to match, is to provide farmers with water in timely and reliable manner to enable them to grow a wide variety of crops that caters to new market demands that farmers face. But this onslaught of groundwater irrigation has brought home its own set of intractable problems such as groundwater over-exploitation and rapid quality deterioration – thereby calling into question the long term sustainability of such an informal irrigation economy. The high energy consumption of lift based irrigation systems as compared to gravity flow systems also makes long term sustainability an issue. Such a deep structural change in irrigation sectors composition, also calls for a paradigm shift in our thinking on irrigation.

Figure 2. Rise of pump irrigation in South and Southeast Asia



Source: Mukherji et al. 2009a

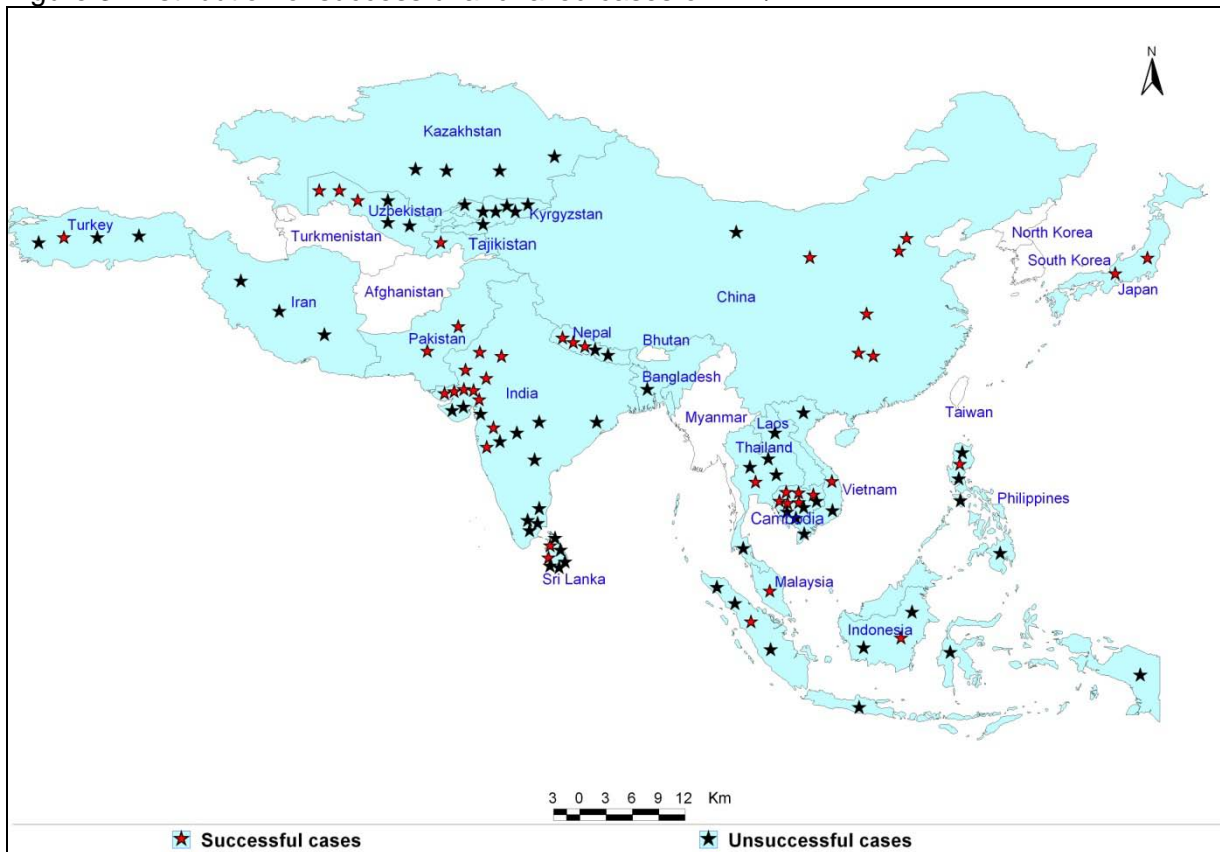
2.3 Earlier failed attempts at institutional reforms in the irrigation sector

Concerned with the poor performance of irrigation systems, donors and governments in Asia had embarked upon a path of institutional reforms way back in the 1980s. Poor operation and deferred maintenance was diagnosed as a problem resulting from lack of involvement of farmers in management decisions. This resulted in policies aimed at increasing farmers’ stake in day to day management of irrigation systems through Participatory Irrigation Management (PIM). Recently IWMI undertook a systematic review of 108 cases of PIM in large scale publicly owned irrigation systems in Asia and found that less than 40% of the documented cases were successful in terms of improving performance of the system after transfer, measured based on a number of indicators (Mukherji et al. 2009b). While 40% success rate does not seem bad, given the enormity of the problems faced, we need to keep in mind that this success rate is not representative of reality due to two reasons. First, successful cases have a higher

chance of documentation and therefore are not representative of ground realities. Second, and even more importantly, none of these studies were rigorous in terms of impact assessment and were not able to tease out the impact of donor funded system rehabilitation from that of system turn over and PIM *per se*.

Careful econometric analysis showed that chances of success are higher in non-paddy systems as compared to paddy systems and that PIM implemented by NGOs are more likely to succeed than those implemented by government irrigation bureaucracies. Having a dynamic high growth agricultural sector also helps – this explains relative success of PIM in Turkey and in fast growing Indian states of Gujarat and Maharashtra and its relative failure in rice growing economies of Southeast Asia. East Asia, particularly China, boasts of most successful cases of PIM – but PIM in China is less about participation and more about turning irrigation officials into entrepreneurs. In India, reputed NGOs have played an important role in success of PIM, but this model is difficult to replicate due to high investments in terms of time and capacity building involved. Figure 3 shows the distribution of failed and successful cases of PIM across Asia.

Figure 3. Distribution of successful and failed cases of IMT/PIM



Source: Mukherji et al. 2009b

Based on our systematic review, we conclude that successful cooperative action in large scale public irrigation systems takes place under a set of very context specific and process intensive conditions – conditions that are difficult and costly, if not impossible to replicate elsewhere. We also argue that lack of replicability of successful cases of PIM is not an issue of poor implementation or enabling conditions, as it is generally thought (FAO, 2007), but is related to conceptual weakness of the PIM model itself.

The first conceptual weakness stems from the assumption that community managed irrigation systems are analogous with public irrigation systems and therefore farmers would be able to manage these systems just as well as they have managed community irrigation systems for centuries. Hunt (1989) carefully analyzed the spuriousness of such an argument. Stemming from the first is the second conceptual weakness, namely that irrigators within a command area are a homogenous group of people with similar interests and stake in the system. This is not true given the very different stakes the head reach and the tail end farmers have and hence the difficulty in engineering successful farmer management in public irrigation systems. The third conceptual weakness is the most glaring of them all. The most important problem facing the public irrigation system has been diagnosed to be the lack of incentive of the irrigation bureaucracy and their lack of accountability to the user. However, quite paradoxically, in most PIM models, these very same officials are entrusted with the task of turning over their responsibilities and power to the users without any reforms to better align the incentives of the irrigation managers with those of the users (Suhardiman 2008).

2.4 Recent attempts at public private partnerships (PPP) in the irrigation sector

Conventionally, PPP in irrigation has been defined as the involvement of the private sector in partnership with the public irrigation department to undertake one or more of the typical irrigation related functions. However, of late, a consensus has emerged that PPP is not so much about finding an “absolutely private” partner as it is about finding a viable “third party” between farmers and government. This third party may be public (e.g. a reformed or financially autonomous government agency) or private (e.g. a private service provider like a contracting firm, or a WUA turned into a private corporation or a cooperative). As a result of this paradigm shift, PPP is often seen as a logical extension of PIM/IMT whereby WUAs would evolve over time and become more commercially driven and professionally managed (World Bank, 2007)

We found 11 cases of PPP in irrigation sector in Asia. Of these, 8 involved large scale canal irrigation schemes and 3 involved publicly owned groundwater projects. We found that the function of the “third party” varied and ranged from providing institutional development and capacity building of the WUA as in the case of Andhi Kola irrigation system in Nepal, to providing O&M, fee collection and water delivery service by “canal contracting” as in China. The earliest documented case of PPP in Asia dates back to 1997 (Bayi irrigation district in China). The others are more recent and in most cases, rigorous impact assessment studies have not been done. In general it seems that PPP has succeeded where at least one or more of the following conditions prevail:

- a) It is possible to exclude potential users given the nature of the technology. This explains why turning over of government tubewells to private entrepreneurs has been easier in all of South Asia than engaging private operators in managing canals.
- b) There exists a strong political will and ability to enforce that will (as in China). It is from China that most cases of successful PPP have emerged. In South Asia, there is a huge mismatch between the state’s ambition and capabilities in enforcing state directives and the civil society and private entities are often as strong as the state.
- c) Farming is a profitable enterprise and there is relative water scarcity. For example, most cases of PPP within India comes from the state of Gujarat, where in response to physical water scarcity, farmers have diversified their cropping systems by moving away from cereal crops to high value crops that gives them

higher return for every drop of water. It is here where dollars per drop of water is high that PPP finds its best niche.

Ironically, these are also some of the conditions under which conventional IMT/PIM is likely to succeed. Therefore, if the intention of implementing PPP is to glean success from cases/regions where IMT/PIM have failed, then there is need for serious re-thinking of the paradigm. Based on a preliminary reading of both IMT/PIM and PPP literature, it seems that systems where subsistence and cereal based cropping still dominate; neither IMT/PIM nor PPP can result in better service delivery. In these cases, more, rather than less government involvement will be necessary, while PPP solutions can be targeted at regions with more dynamic agrarian sector.

2.5 Water pricing reforms in the irrigation sector

“Getting the prices right” is a mantra often used in the irrigation sector. It is said that a major reason for the inefficient and ineffective use and delivery of water is that its opportunity cost does not reflect its scarcity. Therefore, water price that reflects this would send correct signals to the farmers to use it more efficiently than they do at present and this will in turn help balance demand and supply of irrigation water. A related objective is also to recover irrigation costs in order to invest it back into the system. For most parts of 1990s, water pricing seemed like an ideal solution, at least in theory. However, emergence of evidence since the last decade and a half has put into doubt some of the premises. For one, it was found that volumetric pricing, often recommended as the best way of going about pricing irrigation water in order to reduce demand, does not really affect farmer’s demand for water (Molle et al. 2008). This is because there is a huge gap between the price and value of irrigation water and that price of water needs to be raised by a substantial amount before it will have any impact on farmer’s demand for water. However, such steep increases will reduce farm incomes substantially and is not politically feasible to implement (Hellegers and Perry, 2006). However, if the objective is to recover the O&M costs through water pricing, it can be just as well achieved through traditional non-volumetric water pricing (or area based charging). Using volumetric water pricing is even a greater challenge in developing countries. While Australia does have volumetric water charging system, the purpose is not so much to balance supply with demand, but to ensure that water goes to the highest value and most productive uses. But then, Australia does have a long history of water rights and other supporting institutions and it may not be easy to replicate them in the developing countries (Chartres and Varma, 2010).

2.6 Some recent techno-institutional innovations in the irrigation sector

While state crafted initiatives such as PIM/IMT and volumetric water pricing has floundered, several farmer led innovations, both technical and institutional have emerged. Most of these innovations are aimed at reducing transaction costs cooperation and increasing the reliability and flexibility of the irrigation systems. One particularly interesting innovation relates to what are called ‘melon-on-the-vine’ system found in China’s Zhanghe irrigation system (Roost et al. 2008) and ‘diggis’ found in Rajasthan’s Indira Gandhi Nahar Pariyojana (IGNP). Here intermediate structures such as ponds or tanks are used to store water from the canals and used as and when needed by the farmers. Such a design helps in increasing flexibility of the system and mimics the reliability and timeliness of groundwater irrigation (Amerasinghe et al. 2010). Incentivized irrigation managers in public irrigation schemes in China offer another such innovative model where the irrigation managers’ incentives are aligned to meet those of the farmers (Johnson III et al. 1998). The final example of innovative solution comes from two

irrigation schemes in the Indian state of Maharashtra. Here, faced with the problem of obtaining farmers trust that equitable distribution of canal water is indeed possible, the manager of one water user's association (Shri Ram Pani Vapar Sanstha in Pimpalnare village) convinced the farmers to lay down individual pipelines to distribute water from the tertiary canal. This ensured that every farmer got an equitable share of the canal water, which would not have been possible under the business as usual scenario. In another village in nearby Nasik, farmers have designed an equally innovative design, where the canal water is first stored in a tank and then distributed to individual farmers through specially designed equal discharge pipelines. Investments in the pipelines are again made by individual farmers, while the tank is maintained collectively by all (Bhamoriya et al. 2009).

3. How can we revitalize Asia's irrigation?

From the foregoing discussion, it is clear that there is a need to produce more food with the available water resources and for that purpose, Asia's irrigation systems need to be revamped keeping in mind that future irrigation systems will need to be efficient and flexible to meet the demands of many sectors, including farming, fishing, domestic use and energy supply. These systems would need to generate more value per drop of water and enable farmers to respond to challenges posed by volatile market conditions and climate change. How is this to be done? Solutions, we posit, need to be region specific, because, the challenges facing these regions are different.

IWMI and FAO, in consultation with numerous other national partners have recommended a five pronged strategy for revitalizing Asia's irrigation. The section below summarizes these strategies, while in the last but one section of this paper; we provide region specific priorities and investable options.

Strategy 1: Modernize yesteryear's schemes for tomorrow's needs

In Asia, most irrigation schemes were built before the 1970s, and have operated for 40 years and more and now needs to be modernized – both technically and institutionally, for example by being redesigned, operated and managed for a range of uses. Smart irrigation technologies, both old and new, will be essential to meet changing demands. For example, surface irrigation schemes could be used to recharge aquifers or fill intermediate storage structures, such as farm ponds, providing farmers with greater reliability and control. Meanwhile institutional changes that lead to flexible and responsive management will be vital for mitigating against, and adapting to, climate change.

Strategy 2: Go with the flow by supporting farmers' initiatives

While the area of surface irrigation has remained stagnant or been shrinking, farmers in South, East and Southeast Asia have raised yields using locally adapted irrigation technologies to scavenge water from surface sources, waste-water and groundwater using cheap motorized pumps. There are opportunities for investors to identify successful initiatives and direct funds towards schemes that emulate farmers' methods. New models are needed for managing groundwater in areas where 'individualistic' pump based irrigation has largely replaced centralized surface irrigation.

Strategy 3: Look beyond conventional PIM/IMT recipes

Efforts to reform large-scale irrigation schemes by transferring management to farmers have had less-than-expected success throughout Asia. Many believe that the private sector could help irrigation entities improve water delivery, but it needs to be tested. For

example, irrigation departments could outsource irrigation services, create public-private partnerships or provide incentives for irrigation officials to act as entrepreneurs in publicly managed operations. The roles government and the private sector would play in maintaining and operating irrigation systems should be clearly defined. There is a need for increasing accountability of the irrigation staff towards their clients (farmers) and for this purpose, there is a need for formulating better irrigation performance benchmarks.

Strategy 4: Boost knowledge through training

If new approaches are to be successful, investors will need to direct funds towards training existing staff, attracting new talent through forward-thinking curricula and realistic remuneration packages and building the capacity of all stakeholders (including the irrigation bureaucracy). Initiatives might include updating engineering courses in universities, conducting in-depth training workshops for farmers and irrigation officials, and revamping irrigation departments to empower their workforces.

Strategy 5: Invest outside the irrigation sector

The irrigation sector is embedded within Asia's wider political economy and therefore affected by external forces. Policies and programmes that influence agriculture, both directly and indirectly, come to drive developments in irrigation and it will become even more pronounced in the future. Framing policies to ensure external influences on water sector are properly understood and planned is one way to indirectly influence irrigation performance.

In sum, the strategy is to look for solutions that work in practice and these need not necessarily be the 'text book' first best solutions. In much of the developing world, indeed, the 'second best' solutions often hold the key to successful policy changes (Molden et al. 2010).

4. Region specific strategies

As already mentioned, we need region specific strategies since the challenges are different as are the priorities in these regions. In Central Asia, the problem is vast and dilapidated irrigation infrastructure that needs urgent rehabilitation, but that alone, would not suffice unless there are trade reforms in the overall agricultural sector. In Southeast Asia, while current irrigation schemes continue to under perform, the countries in the region are making new investments in hydro power projects and the challenge here is to establish synergy with the irrigation sector and use these investments for poverty alleviation. South Asia may as well be the region beset with most intractable problems. Billions of dollars have been invested in surface irrigation schemes, which are functioning sub-optimally by all accounts. The farmers in the meanwhile have re-configured irrigation systems by investing heavily in groundwater irrigation leading to questions about long term sustainability of groundwater in large parts. The challenge here is to "reinvent canal irrigation" by making it as responsive as groundwater irrigation.

4.1 Strategies for Central Asia

In Central Asia, while direct intervention in the irrigation system through rehabilitation and creation of strong irrigation bureaucracy and empowered water users associations (WUAs) is needed, what is even more direly needed is intervention outside the irrigation sector in the form of larger agricultural sector reforms. IWMI and its partners have been experimenting with IMT models in the Ferghana valley and these have been successful so far. There is also a scope for maintaining current levels of production while reducing

area under irrigation through increasing water productivity. However, without proper incentive structures of trade and pricing, farmers initiatives are stifled. Another problem plaguing the regions irrigation sector is that of poor drainage and resultant water logging. During the Soviet times, large capacity groundwater wells were used to provide vertical drainage, but these have fallen into disuse since then. This makes Central Asia an exception to the rule and here use of groundwater for irrigation has declined since early 1990s (Rakhimov 2005). To reverse this trend and also to cope with water logging, planned and coordinated use of groundwater and surface water needs to be promoted. This calls for investments at two levels. Micro-level investment will involve initiating pilot schemes to test out different models of groundwater use such as state funded public tube wells or individual private pumps for kitchen garden plots. Macro-level investments in groundwater refers to using groundwater aquifers for storing excess winter flows emanating from upstream countries (due to operation of reservoirs for hydro-power generation) in downstream countries and use it for irrigation in summer season (Karimov et al. 2010). This will also be a possible win-win solution for transboundary water problems plaguing the region. Disintegration of the former USSR has led to massive brain drain in the region. Here, another priority investment area would be building up a cadre of professional water managers well equipped to deal with the future challenges.

4.2 Strategies for Southeast Asia

Much of Southeast Asia is investing in large scale surface irrigation schemes. However, our understanding of the ground realities shows that many of the conditions needed for successful operation and management of large scale surface irrigation do not exist here, though exceptions are Vietnam and parts of Thailand (Johnston et al. 2009). This puts into doubt the achievable rates of returns on these new investments. The farmers on the other hand have been increasingly lifting water from surface sources using portable pumps and use of groundwater is also on the rise. Therefore an important strategy here would be to understand how farmers are using pumps and groundwater and initiate pilot schemes to test different alternatives of delivering irrigation services in places where large scale irrigation projects are not likely to work. Particularly relevant here would be the use of shallow groundwater. Outside of the irrigation sector, rural electrification would be a key investment aimed at making energy available for pumping – but this would only one among the many benefits that rural electrification will bring about. Leveraging linkages between hydropower and irrigation will be a way to go about with rural electrification. Investing in capacity of irrigation bureaucracies in individual countries, so that they do a better job in delivering irrigation services is clearly needed. This is especially true for the low income Southeast Asian countries such as Cambodia, Vietnam and Laos. This is where the government's capacity to govern irrigation is also low and hence needs greater support and investment for improving their capacities. Here too, an emerging trend is rapid industrialization of the agricultural sector and this responds to the demographic fact that few people in the region want to remain engaged in agriculture.

4.3 Strategies for South Asia

Re-engineering or modernizing canal systems to mimic flexibility inherent in groundwater irrigated systems is the top investment priority in the region. This would involve a number of interventions, both hardware (physical) and software (capacity building). Some of the suggested option would be unbundling of irrigation services much on the lines of unbundling of electricity utilities in the region, use of piped delivery from tertiary and below tertiary level, better measurement at all levels, construction of farm level storage ponds to increase flexibility and re-orientation of canal bureaucracy towards

better service delivery. In areas of physical water scarcity, there is huge potential for using precision irrigation and micro irrigation technologies and the time to promote them is now. Investing in managed aquifer recharge will help in controlling groundwater over-exploitation in the region. Farmers across South Asia are investing in supply augmentation through unplanned and ad hoc recharge (e.g. Baluchistan in Pakistan and Gujarat in India). The question is: can this be done systematically and how? In addition, much of the important investments will lie outside the irrigation sector. For example, investment in rural electrification and reforming the electricity sector will have a much

Table 2. Summary of region specific strategies for revitalizing Asia's irrigation

Region/ Strategy	Modernize (technically and institutionally)	Go with the flow	Look beyond PIM/IMT	Expand capacity and knowledge	Invest outside the irrigation sector
Central Asia	Rehabilitate drainage systems; Use saline and brackish drainage water; Invest in groundwater to facilitate drainage;	Support higher value crops and improve technical infrastructure to help farmers get higher value per unit of water	Re-examine current WUAs in light of their poor performance; Re-engage government in management of irrigation	Invest in capacity to compensate for loss of expertise after 1991; Invest in better extension services	Reform agricultural sector by removing crop based quotas Invest in co-management of aquifers and hydropower
Southeast Asia	Modernize to re-configure rice paddy systems for multiple cropping; Modernize irrigation bureaucracy	Invest in conjunctive use of surface and groundwater; Invest in long term planning for utilization of groundwater resources	Emulate successful examples from China in pockets of high growth; Re-engage government in poorer countries	Build capacity of irrigation bureaucracy for better service delivery	Use hydro-power schemes for irrigation and poverty alleviation; Reform agricultural policies to encourage crop diversification
South Asia	Re-engineer irrigation schemes through better measurement, farm storage, piped delivery systems	Managed aquifer recharge in groundwater stressed regions	Incentivised service delivery models in dynamic areas and re-engage government in poorer ones	Re-orient irrigation bureaucracy to adjust to changing rural realities	Invest in rural energy sector roads and markets

higher impact on groundwater use than any groundwater regulation will ever have. Investment in rural roads and markets too would be crucial given the move towards diversification of agriculture in India and other countries in the region. Table 2 lists these strategies and places them within the broad framework of 5 strategies mentioned above.

5. Conclusion

Asia has one of the most extensive irrigation infrastructures in the world and much of it was constructed in 1960s and 1970s when increasing production of cereal crops to avert imminent famines was the main concern. Since then, Asian economies have changed in myriad different ways. Within Asia, countries are at varying levels of development. It is therefore, evident that irrigation infrastructure created in the 1960s and the 1970s needs to be adapted to meet the future challenges – the most important of which is catering to farmers demand for timely and reliable water supply to support largely diversifying and high value agriculture. In this paper, we outlined five main strategies that can be used for revitalizing Asia's irrigation and suggested concrete ways of doing so.

We posit that nature of the challenge will determine the extent to which the existing systems can be adapted to the future needs. For example, reliability and timeliness of irrigation water supply will be crucial in ensuring both increased food grains production and high value crops. In addition, for high value crops, on demand pressurized irrigation systems would be at premium. In addition, improved agricultural water management techniques such as zero-tillage, system of rice intensification (SRI) and re use of treated or partially treated waste water would provide windows of opportunity for achieving higher water productivity in high value agricultural systems faced with water scarcity. All these would provide opportunities to reduce E of ET, while interventions aimed at reduced the T component (though bio-technology) may not be ready in the short run.

Challenges posed by climate change would necessitate investments in increased water storage structures, be it surface storage or groundwater storage. In India, already a substantial part of rural development investments are geared towards creation of small distributed storage structure throughout the country side and groundwater recharge is receiving increased attention – both from the national government and from the international donors and farmer communities. The future challenges, would be multi dimensional. Therefore, adapting existing irrigation structures to future needs, in many instances, would involve incorporating multi-functionality (e.g. irrigation and hydro-power generation, or irrigation and flood control or irrigation and waste water re use) in previously single function irrigation infrastructure. An important step towards adapting current irrigation infrastructure to future needs would be carefully assess the systems present 'de-facto' mode of functioning and understand how this serves the interests of the users (farmers) and the irrigation agencies and modernize the schemes based on such understanding.

Investments in irrigation management reforms would also be crucial in adapting present irrigation infrastructures to meet future demands. This will involve investments in not only up gradation of the physical infrastructure, but also investments in 'software', such as capacity building of the irrigation agency staff and practical training for existing water users associations. Investment in professionalization of irrigation management through continuous in-service training program could be a good strategy in this regard. Similarly, another important investment strategy would be to improve data collection and monitoring capability of the national irrigation agencies. Thus software investments would be just as crucial as hardware investments.

6. References

- Amarasinghe, U. A., Palanisami, K., and Singh, O. P. (2010), Managing Unreliability of Canal Irrigation Supply: A Case Study of *Diggies* in Rajasthan, *IWMI Research Report* (forthcoming), Colombo.
- Bhamoriya, V. V. P. Gandhi and N.V.Namboodri (2009), Irrigation Management Reforms and Participative Irrigation Management in India: A Review of the Strategy and Experience, Draft paper submitted to IWMI, Colombo.
- Castillo, G., R. Namara, H. Munk Ravnborg, M. Hanjra, L. Smith, M. Hussein. 2007. Reversing the flow: agricultural water management pathways for poverty reduction. In: Molden, D. (ed). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute
- Chartres, C.J. and Varma, S. 2010. Out of Water: from abundance to scarcity and how to solve the world's water problems. FT Press, New York. 230 pp.
- De Fraiture, C. (2009), *Scenarios of water and food in Asia*, Background Paper # 2, submitted to Asian Development Bank, October 2009.
- De Fraiture, C., Wichelns, D., Rockström, J., Kemp-Benedict, E., 2007. Looking ahead to 2050: Scenarios of alternative investment approaches. In: Molden, D. (Ed.), *Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture*. Earthscan, London; International Water Management Institute, Colombo.
- De Fraiture, C., X. Cai, U. Amarasinghe, M. Rosegrant, and D. Molden. 2004. "Does International Cereal Trade Save Water? The Impact of Virtual Water Trade on Global Water Use." *Comprehensive Assessment of Water Management in Agriculture*, Colombo.
- Falkenmark, M., M. Finlayson, L. Gordon. 2007. Agriculture, water and ecosystems: avoiding the costs of going too far. In: Molden, D. (ed). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute
- Faures, J. , M. Svendsen, H. Turral. 2007. Reinventing irrigation. In: Molden, D. (ed). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute
- Food and Agricultural Organisation of the United Nations (FAO), 2007. Irrigation management transfer: Worldwide efforts and results, *FAO Water Reports # 32*, IWMI and FAO.
- Hellegers, P.J.G.J and C. J. Perry (2006), Can Irrigation Water Use Be Guided by Market Forces? Theory and Practice, *International Journal of Water Resources Development*, Volume, Issue 1 March 2006 , pages 79 - 86
- Hoekstra, A.Y., and P.Q. Hung. 2005. "Globalisation of Water Resources: International Virtual Water Flows in Relation to Crop Trade." *Global Environmental Change* 15 (1): 45–56.
- Hunt, R.C., 1989, Appropriate social organization? Water user associations in bureaucratic canal irrigation systems, *Human Organization*, No. 48, November 1989.
- Johnson III, S. H.; M. Svendsen; and X. Zhang. 1998. Changes in system performance in two Chinese irrigation systems as a result of organizational reforms. *Irrigation and Drainage Systems* 12: 289–309.
- Johnston, R.M., C. T. Hoanh, G. Lacombe, A. Noble, V. Smakhtin, D. Suhardiman, S.P. Kam, P.S. Choo. 2010. Rethinking agriculture in the Greater Mekong Subregion: how to sustainably meet food needs, enhance ecosystem services and cope with climate change. Colombo, Sri Lanka: International Water Management Institute (IWMI). 24p.
- Karimov, A., Smakhtin V., Mavlonov, A. and I.Gracheva. 2010. Water 'Banking' in the Fergana Valley Aquifers - A solution to water allocation in the Syrdarya River Basin? *Agricultural Water Management*. DOI: 10.1016/j.agwat.2010.04.011
- Molden, D; J. Lautze, J.; T Shah; M. Giordano; L. Sanford. (2010). Governing to grow enough food without enough water: second best solutions show they way. *International Journal of Water Resources Development*, 26(2):249-263
- Molden, D, T. Oweis, P.Steduto, J.W. Kijne, M.A. Hanjra, P.S. Bindraban. 2007b. Pathways for increasing agricultural water productivity. In: Molden, D. (ed). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute

- Molden, D., R. Sakthivadivel, C.J. Perry, C. De Fraiture and W.H. Kloezen. 1998. Indicators for comparing performance of irrigated agricultural systems, IWMI Research Report 20, Colombo: International Water Management Institute
- Molle, F., J.P. Venot and Y. Hassan (2008). Irrigation in the Jordan Valley: Are the water pricing policies overly optimistic? *Agricultural Water Management* 95: 427-438.
- Mukherji, A., B. Fuleki, T. Shah, D. Suhardiman, M. Giordano and P. Weligamage. 2009. Irrigation reforms in Asia: A review of 108 cases of irrigation management transfer. Background paper # 3. Submitted to Asian Development Bank, October 2009.
- Mukherji, A., T. Facon, J. Burke, C. De Fraiture, J. Faures, B. Fuleki, M. Giordano, D. Molden, and T. Shah. 2009. *Revitalizing Asia's irrigation: To sustainably meet tomorrow's food needs*. IWMI, Colombo, Sri Lanka and Food and Agricultural Organization, Rome, Italy. 39 p.
- Rakimov, S.K. (2005), Regional experience in solving water problems in Uzbekistan, in *H. Vogtmann and N. Dobretsov (eds.), Transboundary Water Resources: Strategies for Regional Security and Ecological Stability*, Springer, pp. 43–54.
- Rosegrant, M., Cai, X., Cline, S., 2002. World water and food to 2025. Dealing with scarcity. International Food Policy Research Institute, Washington, D.C.
- Roost, N., X.L. Cai, H. Turrall, D. Molden and Y.L. Cui (2008), Adapting to intersectoral transfers in the Zhanghe Irrigation System, China: Part II: Impacts of in-system storage on water balance and productivity, *Agricultural Water Management*, Volume 95, Issue 6, June 2008, Pages 685-697
- Seckler, D., D. Molden, U. Amarasinghe, and C. de Fraiture. 2000. *Water Issues for 2025: A Research Perspective*. Colombo: International Water Management Institute.
- Shah, T. 2008. *Taming the Anarchy: Groundwater Governance in South Asia*, Washington D.C.: The RFF Press.
- Shah T., M. Giordano, J. Wang. (2004). Irrigation institutions in a dynamic economy: What is China doing differently from India? *Economic and Political Weekly*, 39 (31): 3452-3461.
- Suhardiman, D., 2008, *Bureaucratic Designs: The Paradox in Irrigation Management Transfer Policy in Indonesia*, Wageningen University, the Netherlands, PhD thesis.
- Wichelns, D. 2004. The Policy relevance of virtual water can be enhanced by considering comparative advantages. *Agricultural Water Management* 66(1):49-63.
- World Bank (2007). *Emerging public-private partnerships in irrigation development and management*, Water Sector Board Discussion Paper Series, Paper No. 10, May 2007. The World Bank Group.

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