Small-scale irrigation: Is this the future?

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Abstract

The authors were asked to answer the question 'small-scale irrigation: is this the future?'. Taking as a starting point the analyses and of the IWMI-FAO-ADB study on Revitalizing Asia's Irrigation and its key strategies, the paper compares atomistic irrigation, traditional small-scale and large-scale irrigation options, outcomes and potentials in their socio-economic and river basin environments. Atomistic irrigation has exploded, river basins are closing and energy prices are soaring. This new reality, its benefits, its sustainability crisis, but also the potential for new strategies that this phenomenon has demonstrated must first be acknowledged.

In most countries and river basins, additional development of irrigation at whatever scale is not an option and the focus will be on improving the productivity and sustainability of existing systems. In areas where irrigation development is still possible, options remain open. Demography, market pull, water constraints and energy will largely determine the mix of atomistic, small-scale and large-scale irrigation and their evolution, expansion and decline over time.

The paper explores tactics and strategies for the modernization of existing and the potential for new large-scale systems and for supporting and sustaining atomistic and small-scale irrigation, institutional and policy innovations, and tools to facilitate dynamic planning and management of the sector, the evolution of different systems and the design of measures to support an enabling environment.

A considerable body of knowledge exists on how to support these strategies, transform large-scale irrigation systems and promote various forms of atomistic, small-scale and large-scale irrigation systems. Tools that support long-term sectoral planning and management for future investment and the design of measures to support an enabling environment are proposed. The deployment of sound water accounting and auditing systems will be critical. Planning and policy mechanisms will require looking outside the irrigation sector and this is often where effective interventions will be found.

We need to move from competition and conflict between atomistic, small-scale and large-scale irrigation to a fluid logic of complementarily, combination and convergence. For this to happen, the virtual reality of official agency outlooks, imported frameworks, and descriptions of the sectors and the basins will often need to be reformed, as a preliminary to the reform of the institutions and programmes that embody them. Then, the mobilization of resources from the public sector, the private sector and water users can be greatly enhanced and result in positive outcomes and more sustainable results, and enable new solutions to old problems that have long nagged the sector.

Changing the outlook of the sector and effecting the necessary structural and policy reforms, which are required to change decision-making on future investments in the sector will be difficult. Capacity building and changing practice and results on the ground, together with the adoption of robust monitoring and evaluation systems for investment and policy results, can serve as a basis for developing a broad constituency to effect the changes in governance and policy that will ultimately be needed, and assist in shaping investment to facilitate these changes.

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1. Introduction

The writers of this paper were invited to answer the question 'small-scale irrigation: is this the future?' by exploring both the potential and options for small-scale irrigation in Asia and the counterfactual: the potential and options for large-scale irrigation. The question is framed in the usual terms of the debate on irrigation development in the region. But is it a good question? Where and when is it a good question? Is a more effective classification necessary? And are the usual terms of the debate pertinent and helpful? Certainly, in view of the enormous investments required in agriculture and in the irrigation sector, which types of investments should be favored and where, when and how is an important question. Gross cumulative investment requirements from 2005 to 2050 amount, for South Asia, to US$ 265 Billion for expansion and improvement of irrigation and, for East Asia, to US$ 288 Billion (Schmidhuber et al., 2009). This paper, instead of the dichotomy between large-scale and small-scale irrigation, will use three categories: atomistic irrigation, traditional small-scale irrigation and large-scale irrigation. Traditional small-scale irrigation refers to small community-managed irrigation systems, either traditional or modern-built, and large-scale irrigation refers to large irrigation systems with a formal management structure. Atomistic irrigation, as defined by Tushaar Shah, refers to farmers using locally adapted technologies to scavenge water from surface water and groundwater (Shah, 2008). Cheap pumping technologies have led to an explosion of largely unregulated pumped irrigation and groundwater use in Asia: this rise of atomistic irrigation has been the most significant phenomenon of the past decennia. India and China now count 39 million ha and19 million ha irrigated by groundwater, respectively (Siebert et al., 2010).

Building on the analyses and key strategy recommendations of the IWMI-FAO-ADB study on Revitalizing Asia's Irrigation (Mukherji et al., 2009) presented at this conference in an earlier session (Mukherji et al;, 2010), the paper will try to compare atomistic irrigation, traditional small-scale and large-scale irrigation options from different perspectives, including economic, social, and environmental perspectives, in their socio-economic and river basin environments and return to the key drivers of change: demography, market pull, water constraints and energy. The paper will then explore tactics and strategies for the modernization of existing systems and the potential for new large-scale irrigation systems. Options to support and sustain atomistic and small-scale irrigation in different socio-economic and water contexts, as well as institutional innovation and policy considerations will be explored. New tools to facilitate the dynamic planning, management and financing of the sector and evolution scenarios for different types of irrigation systems over time and the design of measures to support an enabling environment will be proposed. Finally, the paper will draw out some conclusions and key messages.

2. Major trends in irrigation in Asia and key strategies for revitalizing irrigation

The IWMI-FAO-ADB Study on revitalizing irrigation in Asia (Mukherji et al., 2009) clearly highlights the nature of the challenge facing the sector. Unless significant water productivity gains are realized, the region simply has insufficient water and land resources to sustainably feed its population. The study indentifies three major trends affecting the irrigation sector in the region. Firstly, changing food demands are requiring shifts in agriculture and agriculture water management and provide farmers with new opportunities. Producing food for increasingly meat- or milk-based diets requires more water and growing a range of crops requires a different irrigation regime than that needed to supply water to large areas planted with one or two cereals. Secondly, state-built irrigation schemes are under-performing, forcing farmers to invest on their own. While this has resulted in substantial economic and productivity gains, this unregulated development has also frequently resulted in excessive pressure on resources. Finally, irrigation management transfer and participatory irrigation management have not lived up to their expectations. As a response to these trends, the study outlines five major strategies to revitalize irrigation in the region to sustainably meet tomorrow's food needs.

1. Modernize yesteryear's schemes for tomorrow's needs
2. Go with the flow by supporting farmers' initiatives
3. Look beyond conventional PIM/IMT recipes
4. Empower all stakeholders through knowledge
5. Invest outside the irrigation sector

3. Tipping the scale: factors affecting the selection of irrigation investment options

These 5 key strategies are both necessary and desirable. This section explores issues related to economic, social, and environmental benefits of various types of irrigation systems, related to tactics and policies, and to the decision-making and management context influencing local and official choices. The key issues include:

- Water productivity
- Economic costs and benefits
- Poverty reduction
- The water-food-energy nexus
- Environmental impacts
- Multiple uses and functions
- Drivers for development and water use
- Water availability and closing river basins
- Institutional actors: the nature of irrigation agencies
- Role of integrated water resources management
- Impact of climate change

3.1 Water productivity gains

Water productivity is usually expressed in quantity of output (total biomass or harvested product) or value (money) per unit of water consumed (evapo-transpiration). The largest gains in terms of water productivity are achieved where yield and productivity levels are low (Molden et al., 2007). Rainfed agriculture still currently plays a dominant role in producing the region's food supply and millions of poor farmers depend on rainfed agriculture to support their livelihoods. They are the most susceptible to climate vulnerability and will be most affected by changes in rainfall patterns due to climate change. Although the proportion of future food production that could or should come from rainfed or irrigated agriculture is a subject of debate, and there is no doubt that the Region's food security hinges on improving irrigated water productivity, there are several compelling reasons to invest in water management in rainfed agriculture. Actual yields are low and the potential to increase productivity is large. Investment costs in rainfed areas tend to be lower than in irrigated agriculture. Upgrading rainfed areas through investments in soil and water conservation, water harvesting techniques and supplemental irrigation can double or even quadruple productivity in drought-prone tropical regions (Rockstrom et al., 2010) and up to sextuple for some crops in India (Sharma et al., 2010b). Investment in agricultural water management in a large number of countries often remains excessively focused on formal irrigation, forsaking equity and productivity gains (Facon, 2010).

Is there is a clear-cut case for investing primarily in small-scale irrigation? Not necessarily. On the one hand, informal irrigation has been boosted by the development of formal irrigation and is often dependent on bulk water supply to the landscape and groundwater recharge provided by the formal systems. On the other hand, it is now increasingly understood that medium- and large-scale irrigation systems are, with only a few exceptions, multiple use water systems. Crops frequently only consume a fraction of the water supplied to the systems' command areas. Other uses and services can have much higher value per unit of consumed water, for either tradable goods and services (water supply, energy, industrial users, non-irrigated parts of the landscape benefiting for the bulk water supply), or goods and services that are not necessarily traded (aquatic resources, flood mitigation and groundwater recharge). Finally, the overall economic impact of the irrigation development on the rural economy by development of upstream and downstream services is related to the density of irrigated production. This density can be achieved either by focusing irrigation development on large command areas, developing a large number of small scale systems, or a very large number of individual or very small scale atomistic systems.

Is there is a clear-cut case for supporting the expansion of atomistic irrigation outside of existing large-scale irrigation systems? Not necessarily either. There are good reasons for promoting it within commands. Informal irrigation contributes significantly to the overall productivity of the command areas by allowing a large number of seasons and crop diversification. Development of private or informal tube-well irrigation for vertical drainage can also alleviate the salinity and waterlogging problems that depress the productivity of surface irrigation systems, as in the Pakistan Indus system (Shah, 2008).

Are there no significant productivity gains to be achieved in large-scale irrigation systems? Yes, there may be. The productivity of many such systems is low and there is much that can be done to improve their productivity through improved service delivery (Renault et al, 2007). This is particularly the case for South Asian system, but also for a large number of rice irrigation systems in Southeast Asia, where yield gaps are significantly wider than for East Asia (De Fraiture, 2009).

But what about irrigation systems that are already highly productive and close to potential water productivity? Prospects for significant increases in potential water productivity in major crops are limited in the future (Molden et al, 2010). For highly productive and developed irrigation systems, improving productivity in one area will most likely result in increasing water consumption, thus making less water available for other users. In other words, this will result in reallocation of water (Perry and al,. 2009). Does it mean that we should leave these systems alone? Not necessarily. If it becomes necessary to decrease agricultural water consumption to satisfy other uses, facilitating a switch to less water demanding or more profitable crops is a potential strategy. There may still be opportunities to decrease non-beneficial consumption, or to increase the productivity of beneficial water consumption by switching to controlled deficit irrigation practices. The objective may not be related to water but to increasing staff costs or staff depletion of irrigation agencies, increasing labor shortages and off-farm employment opportunities for farmers, or decreasing the costs of pumping for operators or for farmers. The main objective may be related to water quality:

reducing non-source point pollution to protect the aquifers or downstream pollution by drainage effluents or reducing losses to sinks (non-recoverable return flows). But is it that simple? Decreasing water allocation and duties by the system may result in farmers simply becoming better at capturing other sources of water starting with rainfall with a resulting reduced drainage from the command area, with potentially significant impacts downstream or additional water streams (or aquifers), repeating the evolution of irrigation systems designed with low initial duties.

In summary, efforts to improve water productivity should focus on areas where poverty is high and water productivity is low areas of physical water scarcity where competition for water is high, areas with little water resources development where high returns from a little extra water use can make a big difference, and areas of water-driven ecosystem degradation, such as falling groundwater tables, and river desiccation, but they will prove ever more difficult (Molden et al., 2010). A caveat to bear in mind will be that improving water productivity will usually entail improving water consumption per unit of land (Perry et al., 2009).

3.2 Economic costs and benefits

Irrigation is the largest recipient of public agricultural investment in the developing world (IEG World Bank, 2001) and evaluation of its economic benefits has thus been a focus of much scrutiny. In spite of their high initial costs and poor reputation, classical large-scale irrigation systems fare relatively well in terms of economic returns. A comprehensive review of past irrigation development projects shows that, in spite of relatively high costs per hectare (between US$ 3,900 to US$ 9,700/ha for new projects), irrigation development projects have a high success rate as defined by an internal rate of return higher than 10% (Inocencio et al., 2005). The bigger the program and the larger the command area of the irrigation systems, the higher the success rate and internal rate of return. A more recent study by the World Bank[3] shows a high average rate of return (average 22%) with an average costs per ha of US$ 6,600/ha. Rehabilitation projects have a lower cost per ha (from 800 to 3900 US$/ha for the IWMI study and US$ 2,900/ha for the World Bank study) and a higher success rate (Inocencio et al., 2005). Rates of return and success rates are highest in East Asia, followed by South Asia with Southeast Asia exhibiting the lowest success rates and rates of return (Inocencio et al., 2005).

Major factors of poor performance were found to be: overestimation of command area, costs over-runs, and delays in construction. The overestimation of initial command areas may actually be due to: i/ farmers becoming free riders (by developing informal irrigation in and around the developed areas); ii/ upstream informal irrigation development (Shah, 2008, Calder et al., 2007a) that reduces outflows for upstream catchments; iii/ upstream formal irrigation development (Molle et al, 2009). In intensively developed closing river basins like the Krishna Basin (Venot, 2009) and the Bhavani river basin in Southern India (Lannerstad et al, 2009), all three factors may at play. In spite of billions of US dollars invested in the development of new surface irrigation systems in South Asia, their total command area has been declining.

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[3] IEG World Bank, 2006. Water Management in Agriculture, Ten Years of World Bank Assistance, 1994–2004. The International Bank for Reconstruction and Development / The World Bank, Washington, D.C.

Critics of irrigation development claim that high rates of return do not factor in negative externalities. Meanwhile many in the irrigation community estimate that the positive evaluation of impacts could be higher if benefits accruing from a multiplier effect or transfer of water to uses with a higher economic productivity (IEG World Bank, 2006), the valuation of positive externalities and non-tradable benefits (such as flood mitigation, estimates at 5 times the value of rice paddy production in Japan) or tradable services are factored in.

Community-scale irrigation systems typically have a lower cost per hectare than large and medium irrigation systems. But what do you get for this lower price? Usually, a lower level of service (for instance by selection of proportion flow division as a design criteria), less reliable water supply (run-off river schemes) or high operation costs (water supply by pumping). The costs for providing a similar level of reliability of water supply or service for a community irrigation system would tend to decrease with the size of the system. As a result, overall productivity and EIRRs are not necessarily higher.

For atomistic irrigation, it is not sufficient to look at development costs per hectare. These are typically much lower than those of new large-scale formal irrigation systems. One also needs to consider the cost per development unit (i.e. pump set, borehole, individual drip or sprinkler system, bucket system or treadle pump), the payback period (2030 Water Resources Group, 2009), which is relatively quick, and the operating cost. A high cost per unit may prohibit access by individual farmers. This cost or obstacle can be spread by farmers pooling resources or invest, or by the investors expanding their customer base through developing local water markets (Shah, 2008). But the development of pump irrigation can be an opportunity for the mechanization of other farm (threshing etc.) or non-farm activities, or be part or of benefit from farm mechanization (a small tractor used to power a pump). Operating costs related to energy consumption affect the economics and viability of pumped irrigation. Systems depending on manual energy are vulnerable to increases in the opportunity cost of labor. Systems depending on electricity are vulnerable to increase in energy prices. The recent energy crisis has resulted in millions of farmers using diesel pumps being priced out of the market (Shah, 2008). Decreasing water tables result in both higher unit costs for boreholes, and operating costs (energy), likewise displacing the poorest as possible investors or customers of existing water markets. The economic returns can be spectacularly high when compared to formal irrigation (Shah, 2008).

The economics of small-scale or atomistic irrigation are however usually analyzed at the household, individual or community levels only. At a larger scale, very high overall economic benefits may induce significant negative economic externalities due to reduced flows downstream, shrinking downstream command areas and reduced inflows into reservoirs. Classical community level irrigation development can have significant local social and nutritional impacts locally by eradicating local aquatic resources, or, at the basin level, a significant cumulative impact, say on fisheries by reduced basin connectivity.

3.3 Poverty reduction

The impact of irrigation development on poverty reduction has been demonstrated to the extent that it is now commonly accepted as being very high (IEG World Bank, 2006, JBIC Institute, 2007). Irrigation development alleviates poverty either directly, by increases in agricultural production, income and labor availability (Hussein, 2005; Lipton, 2007), or indirectly by second-generation effects (improved access to education and health, development of services, etc.). Nevertheless, irrigation investments were often a missed opportunity, and could have better poverty reduction outcome if more strategically designed (Darghouth et al., 2006). Likewise, small-scale irrigation development is found to have positive impacts on rural livelihoods for both traditional small-scale irrigation (Angood et al., 2003), shallow tubewells (Angood et al., 2003, Brabben, 2004, World Bank, 2004-2007b) and the development of atomistic irrigation in South Asia has been found to have a much larger impact on poverty reduction than any irrigation government program (Shah, 2008).

Very small investments such as bucket irrigation or treadle pumps or mini drip kits may not have a real direct economic justification but may have a very significant nutrition or household food security impact (DFID, 2003). In the proper context, they can be a stepping stone for investment into an irrigation system with a higher unit costs (such as from treadle pump to shallow tube-wells in Bangladesh (Shah, 2008) or into other businesses. Securing the income stream allows a break out of the poverty cycle. Increasing wealth can lead to greater educational opportunities for children, and the chance to move out of farming altogether[4]. Major issues are related to inequity: inequity of service delivery or water allocation upstream/downstream in particular and more generally related to proximity to the source of supply for technical reasons (Renault, 2007, JBICI, 2006), inequity of access to the water for social, legal, economic or local power structure problems (Hussein, 2005, Shah, 2008). Equity of land distribution is obviously a major factor in the distribution of irrigation benefits (Hussain, 2005, Hussain, 2006) while gender equity aspects combine positive and negative elements.

At policy level, poverty reduction or rural developments under different names have long dominated the rationale for irrigation development, with some justification and level of success. A major poverty reduction impact of the green revolution has been the reduction of the prices of basic commodities. For some time, economic development and poverty reduction have been going rather well hand-in-hand and irrigation-based agricultural development has supported overall development. With the closing of the basins and the rising demand from other sectors, things become more complicated. The demand from other economic sectors increases and they usually have a higher water productivity. The agricultural GDP may be decreasing fast but in terms of employment the agricultural sector may still massively dominate, with widely divergent dynamics according to the regions: in South Asia, rural populations are still increasing and are expected to peak in 2030 while for Southeast Asia and East Asia, the demographic transition is occurring very fast and will continue (Shmidhuber et al., 2009). Worse, the present income disparity between rural and urban areas and agricultural productivity, wages and earnings is predicted to increase in all sub-regions in Asia. One rural area's water-based poverty reduction may affect other poor users downstream.

One developing country, the Peoples' Republic of China, is attempting to balance food security objectives, economic growth objectives, rural/urban income disparity and rural exodus objectives. Basically, total water allocation to agriculture has to remain at present levels while production needs to increase significantly to sustain high national self-sufficiency levels in grains and overall allocation to rural areas for irrigation, rural water supply and other economic activities has to increase. For irrigation, this entails decreasing water allocation to existing irrigation systems while increasing their productivity, including on

[4] It is often a deliberate exit strategy, which underpins efforts to extract value from aquifers without concern for their sustainability.

the existing large scale irrigation systems, and reserve the water allocation credit to develop rural water services and irrigation, essentially of the small scale type (China MWR, 2009). In short, a "new socialist countryside" goal coupled with a "water saving society" goal result in a shift towards small scale irrigation development in new areas, made possible by massive investments in modernizing and improving the productivity of all existing irrigation systems. In India, both state and central governments have become aware of the poverty reduction potential of interventions such as rainwater harvesting, groundwater recharge, small reservoirs, farm ponds etc. and invest in them massively within dedicated programs or as components of poverty reduction programs (Facon, 2010). Whether these end up complementing or competing with concurrent investments in formal irrigation or downstream areas is a serious question. Friction and conflict between national-level food security concerns and local poverty alleviation and development programs developed under decentralized government processes will increase. Countries will want to secure strategic food crops in breadbaskets while local water users and governments will beg to disagree as they see these crops or agriculture as poverty traps – and will behave accordingly.

3.4 The water-food-energy nexus

The water-food-energy nexus can take several forms. At the farmer or household level, it affects access to irrigation, sustainability of irrigated farming, the type of on-farm irrigation technology, the shift to higher value crops, etc. At a slightly higher level, it may affect the viability of the water supply, or the overall economics of irrigation system operation and maintenance. At both levels, there may be opportunities for in-line water turbines to generate electricity. At a higher level still, one can distinguish:

- System-level issues of water sharing between hydropower and irrigation;
- River basin and system-level problems of conflict over the management of the resources at seasonal level[5] or daily level (most important for fluctuations in supply generating chaos in service delivery downstream);
- Possible impact of upstream land use on inflow into the reservoir (a conflict over the resource);
- Opportunities for downstream and associated irrigation development by increasing dry season downstream flows, supporting rural electrification (in the Mekong Basin for instance (Johnston et al., 2009)) or allowing to share water resources development or operating and maintenance costs.

At the river basin level however, if damming at whatever scale(s) results in reduced silt loads into the deltas, it can cause them to shrink with severe impact on agricultural production and increased vulnerability to sea level rise, erosion and storm surges.

The impact of groundwater development in South Asia has been analyzed both in depth, in breadth and in detail. These studies were recently synthesized by Tushaar Shah (2008). Massive energy consumption for pumping groundwater has drained the energy sector, affecting the availability of energy to other users and depleting states' coffers. Paradoxically, policies that successfully eliminated electricity subsidies resulted in an increased usage of diesel pumps. This has meant that recent high energy prices may now restrict further

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[5] For example, in the Aral Sea Basin, or in the Red River, where releases for spring rice (both for pumping and supply) result in power outages at the end of the season that affect the industry and millions of users (Tuong, 2009).

groundwater development in areas of abundant and secure groundwater availability, while in some cases electricity subsidies remain in areas where the resources are depleting fast or are threatened by seawater intrusion. Promising alternatives have been demonstrated to be both politically acceptable and effective in dealing with the difficulty of eliminating energy subsidies. In Gujarat and other states, for example, decoupling the irrigation and rural grids at local level and rationing irrigation electric supply to a number of hours per day has resulted in healthier energy utilities, reduced groundwater drawdown, and a boost to rural economic and social development (Mukherji et al. 2009, Shah, 2008). Other approaches, based on demand management by communities in hard-rock aquifers, with a starting point on knowledge and individual interest such as in the Andhra Pradesh Farmer-Managed Groundwater Project (Facon, 2010), or with groundwater recharge as a starting point (Shah. 2009) have been shown to work on the ground. In another context (China), approaches based on groundwater allocation and local groundwater markets are being successfully piloted in "Water Saving Society" pilot counties.

Finally, the development of crops for biofuel production will compete with food crops fro both water and land. The potential water footprint of first generation biofuels can be quite significant (De Fraiture et al., 2010). So can the impact of second generation cellulose-based biofuels if they translate into significant afforestation programs that will increase upstream water depletion.

3.5 Environmental impacts

Previous irrigation development has been achieved at considerable environmental cost. Irrigation in general (and large-scale irrigation in particular) have therefore been largely decried or challenged for environmental reasons. By comparison, the environmental impacts of small-scale irrigation are seen as being small, which has contributed to the "smaller is better" mantra. However the situation is more complicated now. Macroscopic environmental impacts may arise from the massive development of atomistic or small-scale irrigation. Meanwhile, even traditional rice-based paddy systems are found to be significant emitters of greenhouse gases (emitting almost as much as natural wetlands!) in spite of their multi-functionality.

We still seem to be a long way from a comprehensive framework for assessing the environmental impact irrigation at various type, space and time scales and, perhaps more importantly, of a sufficient constituency to support the adoption of a comprehensive framework where a factual assessment of the advantages and disadvantages of each type an scale can be undertaken. However, it can be estimated that a low density of small-scale irrigation development (due to a low density of human settlement) will have downstream impacts that are potentially positive at the local level and negligible at the global level. Meanwhile, there exists a considerable knowledge base on options to reduce the local environmental impacts of irrigation systems and much methodological development is happening. This includes innovative assessment methodologies of irrigation systems (MASSCOTE-based evaluation products for instance (FAO, 2007)) or, at basin-level, water accounting (Calder et al., 2006b) together with direct estimates of water consumption and ET (World Bank, 2004-2007a, Ministry of Water Resources, PRC, 2007) by modeling or remote sensing.

Unfortunately, rural desertification in the upper watersheds may lead, via reforestation, to a decrease yield of the river basins. For densely populated watersheds, to what extent can more intensive land and water use lead to a desirable outcome downstream? This would require that increased runoff and rainfall capture lead not only to increased evapo-transpiration but also increased infiltration that may improve dry season flows downstream. Detailed modeling and monitoring are required to assess the partitioning under different circumstances.

3.6 Multiple uses and functions

The 5th World Water Forum has perhaps been marked by the recognition of the multiple uses of irrigation systems such as fish farming, domestic and industrial water supply, navigation, groundwater recharge and flood mitigation, support to biodiversity, micro-climate, etc.. This increased recognition may lead to more informed decision making leading to an optimization of the various functions of the irrigation systems, to an improved platform for securing financing for overall operation, maintenance and upgrading of the systems, and to substantial changes in operation strategies and supporting infrastructure as multiple service objectives are specifically arbitrated and defined.

3.7 Drivers: demography, socio-economic environment and food prices

At a general and regional level, increases in population and their increasing wealth will drive overall irrigation development and transformation. At the local and national level, irrigation transformation will be governed by the local socio-environment context, including increases in the price of basic commodities. FAO (FAO-RAP, 2007) and the Comprehensive Assessment (Faures et al., 2007, Turral et al., 2010) distinguish between primarily agrarian, transition and post-agriculture or advanced economy, with peri-urban variants. This leads to significant variances in evolution scenarios and supporting strategies for existing irrigation systems.

It is expected that prices of basic commodities will increase in real terms between 15 to 40% in the coming decade (OECD-FAO, 2010). Long-term scenarios taking into account climate change also predict significant increases in real term because of climate change (IFPRI-ADB, 2009). This may ameliorate the fundamentals of the economics of all types of irrigated grain production. Already, certain governments are boosting or dusting off old irrigation development plans while new investors (small scale entrepreneurs, large private companies and sovereign funds) are becoming increasingly significant.

As far as atomistic or small-scale irrigation is concerned, demography, the local socio-economic environment, commodity prices and energy prices will likewise influence the future development of various forms of atomistic or small-scale irrigation development, together with new technology. In South Asia, as the main driver is land rather than water scarcity (Shah, 2008), and as rural populations will continue to increase, atomistic irrigation will remain the most dynamic sector in the short and medium term.

In Southeast Asia, with decreasing agricultural and rural populations and an increasing rural/urban income disparity, the development of classical small-scale irrigation may still be a valid option in predominantly rural areas for poverty alleviation in the short/medium term but this will be a transitory phenomenon. For areas with high population growth, acute poverty, and isolation from markets (for instance, the Visayas region of the Philippines), forms of atomistic irrigation may already be better options than communal irrigation schemes, especially if the latter perform poorly. In transition areas, the development of atomistic irrigation may already be the best bet option, compared with all other forms of irrigation, allowing a leapfrogging over traditional small-scale irrigation development. In these areas, the trend not only for large and commercial farmers but also for small-holders, is the conversion from food crops to industrial mono-crops and tree plantations and orchards, with concentration on highly productive crops (aquaculture or specialized crops depending on access to market. Thinking that merely supporting rainfed grain productivity in these areas by atomistic or small-scale irrigation will reverse these trends is certainly an illusion. It is probable that a new class of more professional and entrepreunerial farmers of a larger size will emerge and will invest in a range of small/medium scale local water mobilization projects and irrigation technologies. In East Asia, where the demographic transition will also be rapid but the number of poor rainfed and farmers in the hinterlands will remain very high, small-scale irrigation will continue to have a bright future in the medium/long term.

These vastly differing circumstances can be synthesized by classifying countries according to the level of formality of their water economies, which is closely linked to their level of economic development. Asian water economies vary from largely informal (South Asia) to formalizing (Southeast Asia) to highly formal (Japan, Korea) (Shah, 2008). In largely informal water economies, informal markets, mutual help and community management will dominate. In formalizing economies, organized service providers will dominate while self-supply and informal community institutions will decline. In highly formal economies, the latter disappear and all users are linked to a modern water industry. This distinction can be valid not only at the national level but also at the sub-national level, as proposed by FAO (FAO-RAP, 2007).

The assessment can be refined. In formalizing countries where irrigation agencies do not reform and remain construction-oriented and non-responsive to farmers' demands, individual responses will continue to dominate resulting in increased anarchy and chaos. Countries with a recent socialist system probably have a level of formality greater than their level of socio-economic development suggests. Lack of transparency in decision-making tends to favor large-scale irrigation investment (either public or private (Hoanh et al., 2009)). For countries with mass democracies and large numbers of farmers, all forms of irrigation now tend to be developed and large constituencies of farmers have to be taken into account for the feasibility of policy options. Countries with single party systems may well have more long-term interests and authority to allocate resources to rural areas or particular target groups.

3.10 Closing river basins vs open river basins, or aquifers and recharge pull?

The dynamics of closing river basins and different types of aquifers are now increasingly well understood. Molle and Wester (Molle et al., 2009) distinguish and analyze four generic processes at work in most river basin trajectories and their drivers: "(i) the overbuilding of river basins; (ii) the overallocation of entitlements; (iii) the overdraft of reservoirs and aquifers; (iv) the double squeeze of agricultural water use, due to declining water availability and quality on the one hand and rising urban and environmental needs on the other." A combination of vested interests, water and irrigation development institutional factors, and political dynamics favor overbuilding which manufactures water scarcity. There comes a point where all possibilities of additional water resources development and supply augmentation or water transfer are exhausted or become prohibitive and sub-basins as well as basins close. At that point, all forms of irrigation are in competition and gnaw at or cannibalize each other. In arid basins, control is easier to maintain because it tends to be concentrated in a few key points and sources of water are few, and the water regime is easy to understand. In more humid basins, this is much more difficult because the hydrology is much more complex and variable, and sources of water are multiple. When river basins are closing, efforts at water conservation or improving water productivity and tend towards a zero-sum game (Perry et al., 2009).

In a similar vein, the general dynamics of groundwater economies have been described for major types of hydro-sociological contexts and also for main types of aquifers (Shah, 2008). Shah's key contention is that, in South Asia, groundwater development dominates and this has reshaped the river basins, creating a substantial groundwater reservoir. The key issue for river basin and higher scale water resources management, therefore, is the management of this groundwater reservoir. This "recharge pull" would also determine the transformation of existing irrigation systems (which move towards mimicking atomistic irrigation or towards conjunctive management for irrigation service level purposes), the sustainability of atomistic irrigation development or the location of new large-scale irrigation systems for bulk conjunctive management.

3.11 Institutional actors: the nature of irrigation agencies

Modern irrigation agencies have been essentially created with a development mission: the development of the country's "irrigation potential" to support rural development and meet the national food demand. Their main programmes therefore consisted in the construction on new irrigation systems, which were then handed over to management outfits in charge of operating and maintaining the systems, essentially with a standardized supply-oriented mode: official operation schedules were dictated by an official cropping pattern that farmers were expected to follow, the whole process being underpinned by bureaucratic processes and management styles. This is supported, on the one hand, by planning procedures, rigid guidelines, design standards, an ecosystem of consulting firms that prepare projects according to standards, education institutions that format new entrants into the agencies' labor force. Career paths in the development branch of the irrigation agencies are typically faster, more prestigious and more rewarding. Together with vested political and economic interests that favor expansion of the irrigation agencies' clientele and new infrastructure construction, this has created a path dependence that shapes the ethos of the agencies, influences investment options and underpins the overbuilding and overallocation processes in the river basins.

Although many efforts have been directed at reforming the irrigation agencies, their functions and their mindsets, they have proven to be most resistant to change. Institutional and management reforms have made some limited advances in transforming their management setups towards a more service-oriented mode, but this has often not affected their construction orientation. Recently, the food crisis, the energy crisis, the economic crisis and climate change have been used as opportunities for these agencies to lobby for continued or renewed financing of irrigation development programmes and annexed water resources development without undergoing significant reform. Whether the new challenges facing irrigation are addressed in and continue to support a supply-driven mode or, on the contrary, trigger the necessary reforms is one of the critical questions facing the sector today, in a large number of countries.

3.12 Integrated Water Resources Management - part of the solution or an obstacle to evolving solutions?

The relevance of classical Integrated Water Resources Management (IWRM) approaches and instruments in highly informal water economies is low, however this increases as economies embark on a formalizing process with a decreasing number of water users (Shah, 2008). As, at the end of the day, decisions on water and who gets what are essentially political, decisions on water allocation to agriculture will be dominated by the political influence and numbers of farmers affected. Classical water institutions such as river basin organizations are not prepared to, or not capable of, making difficult decisions regarding water allocation in the context of closing river basins (Molle et al., 2009). They are certainly not designed for small-scale or large conjunctive management of surface and water resources as envisaged by Shah, or for joint management of water and land, blue water and green water[6], and the mix of irrigation systems. Importing IWRM 'solutions' from developed and temperate countries into poorer countries with high seasonal variability and very complex regimes has a remote chance of achieving the objectives of water resources management, and leads to a multitude of missed opportunities (Facon, 2007).

3.13 Climate change: does it matter?

A priori, other drivers of change in the irrigation sector, pending unpleasant surprises, will have more influence than changes in rainfall patterns or runoff. As a general rule, predicted impacts of climate change will exacerbate current trends. Atomistic irrigation and improved rainfed management will increase in response to increased variability of rainfall, but may not be sufficient in semi-arid and arid areas, or may be viable for a shorter period in areas with decreasing rural population and increasing urban/rural income disparity. Groundwater recharge will be affected while pressure on groundwater resources will increase. Irrigation management strategies that are more flexible, responsive and service-oriented will respond much faster to changing circumstances and will enable farmers to adapt farming systems and adopt new on-farm practices for either climate change mitigation or adaptation. The canal irrigation/pumping mix optimum will shift in favor of canal irrigation as energy costs increase and the need to decrease the energy intensity of irrigated agriculture becomes a policy objective. Generally, the need for the conjunctive management of surface and water resources will become more pressing. Additional surface storage will be needed. Water-based solutions on the storage, water allocation and water productivity sides may not be able to come with the whole range of variability and successive years with severe floods or droughts: increased grain storage will become an increasing necessity at various scales from the local to national and regional levels, to compensate fro increased variability of production or volatility of commodity prices. While useful generic adaptation strategies for main food systems are being developed (Turral et al., 2010), the uncertainties are such that for specific river basins or food systems, in particular the glacier and snow melt systems originating from the Himalayas and the tropical deltas, the large-scale impacts and responses are still uncertain, although the outlook is rather pessimistic.

3.14 Small scale irrigation vs. large-scale irrigation: conflict, competition, complementarily, combination or convergence and confidence?

As has been seen above, the question this paper was requested to answer – small-scale irrigation: is this the future? – does not have a simple answer. First of all, a distinction has to

[6] Blue water refers to liquid water withdrawn for irrigation from rivers, lakes and aquifers and green water refers to rainfall infiltrating the soils and consumed by evapo-transpiration (Falkenmark, 2006).

be made between conventional small-scale irrigation and atomistic irrigation. Atomistic irrigation has supplanted not only large-scale irrigation but also conventional small-scale irrigation in South Asia and has already gained much ground in Southeast Asia and parts of East Asia. There are already circumstances where atomistic irrigation is already a better option than further small-scale irrigation development. In all regions, atomistic irrigation already is the main development in the past and present, or is likely to pick up fast. In remote and low density areas, small-scale irrigation still has a future, but probably only in the short to medium term as transitional phenomenon.

In South Asia, atomistic groundwater irrigation will maintain its dominance for some time to come, but will increasingly have to be rescued by large-scale water development for the recharge or substitution of groundwater irrigation or large-scale overhaul of the electricity grid. At the same time, large-scale irrigation systems have a future if they can morph into a state where they mimic atomistic irrigation. In Southeast Asia, both atomistic and small-scale irrigation may be a good bet, but may be only a transitional support to dwindling smallholder farming in areas of low population density. In areas of higher population density, pathways will diverge according to market access towards forms that support a commercialization of agriculture or are essentially, at least in the short-medium term, oriented towards household food security and resilience. East Asia may be in a better position to balance and orient the development of a mix of atomistic, small scale and large-scale irrigation. In Central Asia, the dominant feature will remain large-scale irrigation with possibilities of groundwater expansion.

Whether the future of these various forms of irrigation is competition for political support or for water allocation, complementarily to fulfill different objectives in different socio-economic context, for groundwater recharge or, within the same command area, complementarily, combination and convergence to fulfill varied levels of service required by farmers or other users will depend greatly on countries, river basins, the typology and each individual irrigation system and even, for large irrigation systems, for different sub-areas of the irrigation system which can vary significantly among each other.

The Revitalizing Asia's Irrigation report (Mukherji et al., 2009) presents a set of generic and desirable strategies that are consistent with general trends. The background paper presented in section 2.1 of this conference (Mukherji et al, 2010) further develops these key strategies into key sub-regional investment options for Central Asia, South Asia, Southeast Asia and South Asia. These are desirable options a priori. But how confident can we be that these options and an optimal mix of atomistic, small scale and large-scale irrigation will emerge in practice? This section has highlighted a number of constraints related to key drivers, both within and outside the water and irrigation sector. Some are political in nature, while some are related to institutional rigidity, path dependence, a poor basis to assess the various pathways or a flawed or impractical toolkit, at least in the short and medium term.

Suggestions that the necessary improvements in the overall decision making and management framework require not only major shifts in policy but also a change in the nature of the democracy (Shah, 2008, Molle et al., 2009) or in the type of government are met by the authors by a degree of cautious optimism and confidence that this will occur any time soon. This leads to the discussion, in the following section, of practical options that can be, and are indeed already being, implemented in some places. Policy options, the general merit of Plan B or second-best solutions, possible strategies to accelerate policy shifts or institutional reform, and new planning instruments that may assist in guiding future hardware and software investments and financial strategies are also discussed.

4. Responses

4.1 Reconfiguring existing large-scale irrigation systems

The purpose of reconfiguring existing large-scale irrigation systems is to adapt irrigation design and operation concepts to changing objectives. These changing objectives are related to satisfying changing irrigation service needs of farmers and the needs of other water users, while fulfilling river basin objectives and improving economic and financial outcomes. This is the essence of the modernization of irrigation management and, as such does not address only hardware changes needed to support operation strategies to support new management and service objectives, but also changes in management and institutional setup to promote service-oriented management on a sustainable basis. The needs of the users and river basin circumstances will change over time and changes in management objectives have to be revised accordingly. Improving management, through better institutions and better technology will require constant adaptation and finessing, with no silver bullets currently on the horizon (Turral et al., 2010), so sustainability has to be seen as a dynamic process that needs to be sustained over time, requiring responsive and flexible institutions, sufficient financing, and considerable capacity at all levels.

The difference between the service provided by the current system and what farmers presently need, which can often be assessed by what they achieve with their own efforts, represents the present gap in irrigation service performance that needs to be met by the system. This gap can be expressed in terms of equity, reliability and flexibility. An increasingly significant component of the service is the lift or pressure at which water is delivered. Finally, the total water availability (sometimes called adequacy) is a significant component of service. A gap in water availability may reflect a gap between the system's initial or official production objectives and farmers' aspirations. A large system may be quite heterogeneous in terms of farming systems and availability of surface water, groundwater and rainfall and this should be reflected in diversified service objectives and water management strategies.

As the large-scale irrigation systems are (with very few exceptions) de facto or officially providers of multiple uses and services, understanding, optimizing and translating these uses into management objectives and operational strategies has to be considered (FAO-RAP, 2007). The multiple uses and roles of irrigation systems and their environmental externalities are often unplanned and emerge during operation, by accident as it were. Reconfiguration entails moving away from the generation of both positive and negative externalities by accident and from the development of autonomous farmers' responses due to neglect by system management, to the explicit management of multiple roles and the explicit recognition of farmers' service and other objectives and of their contributions to overall efficiency and productivity and of the costs thus incurred by them, through their autonomous responses. The search for a new system consists in the search for the most practical, economical options on where, how and at which levels (main system, intermediate distribution, farmers, conjunctive use, etc.) to locate improvements for service delivery (FAO-RAP, 2007). As the price of energy will rise, so will the overall mix shift from pumping to surface delivery, and reduction of energy consumption (for fiscal purposes if energy is subsidized) will become an important objective and opportunities for generating energy within the system will be exploited. The reconfiguration must aim towards increasing water reliability, flexibility and where possible, availability. Where atomistic irrigation reigns, reconfigured systems should increasingly aim at mimicking atomistic irrigation (Shah, 2008).

Considerations related to the need to recharge groundwater in the command area or for river basin management purposes, and objectives related to controlling the water quality of runoff or surface effluents from the system and of groundwater recharge will increasingly influence technical options: where to locate the recharge: conveyance, storage, or fields? store, recycle or treat drainage water (constructed wetland) and/or work on fertilizer and chemicals management at the farm?

Generic tactics to improve the service delivery of surface irrigation systems are well known and tested (Renault et al., 2007). Key options to improve flexibility and reliability and, where possible, water availability, such as farm ponds or intermediate storage, are also increasingly recognized and implemented and have a great potential. The Indira Gandhi Nehar Pariyojna (IGNP) scheme of Rajasthan, India and the melon-on-the-vine irrigation concept at work in Zhanghe, Hubei, China, illustrate the implementation of these concepts in arid and humid climates (Mukherji et al., 2009). In IGNP farm ponds have allowed farmers to switch to sprinklers in a system where bulk water supply continues to be governed under the Warabandi system. In Zhanghe, a multitude of storage at farm and intermediate levels have allowed farmers to adapt to decreasing water allocation from the main water system.

Key strategic questions are highlighted below:

Radical change or gradual change? All systems can benefit from immediate improvements through simple changes easy to implement, focused on improved operation, many requiring minimal changes in the system's hardware, frequently within available budgets. MASSCOTE is a methodology to identify and implement these changes. However, increasingly in South Asia or East Asia, it appears that, in order to mimic atomistic irrigation, more radical changes may be needed (creation of intermediate storage where none existed, conversion of part of the conveyance system to pipes). Where a substantial budget for rehabilitation or modernization is already planned and available, radical options should be considered from the onset. Where budgets are more limited, the introduction of radical options could be limited to a pilot area experimenting if possible with innovative forms of financing by farmers or private operators. Implementation of simple progressive options and restructuring on management and institutions and the development of simple information and monitoring systems that provide a basis for planning of future options should be implemented in all irrigation systems. In practice, this puts the emphasis on re-training and capacity building for long-term modernization and future steps.

What if water availability does not match farmers' needs? If farmers are not "captive" of the system and alternate sources of supply are available, farmers will capture them if they need them. This may not be a problem in Southeast Asia or more humid environments and overall strategies may anticipate and build on this. Water availability can be increased by storage management and demand management. Beyond this, farmers and management will need to accept water resources constraints and adapt seasonal management or crops.

What to do when the water supply is shrinking? When all management improvement, supply augmentation and water conservation options are exhausted, two options are left: a shrinking of the command area and user base of the project or a decrease in the original (usually quite low) water duty. The original promise of the project and its promoters has not been kept. This may be a rather difficult situation politically or in terms of project equity. The command area may already be shrinking for other reasons (urbanization, etc.) and this can be planned ahead.

The power of unbundling. An important principle of modernization of management is the unbundling of management into levels that provide irrigation delivery services to the next lower level. This simple idea clarifies the performance expected from each level of management, and the analysis of costs associated to each level's operation. The type of operator for each level can vary from government to private to farmer-owned and managed. The Jiamakou Irrigation District in Shanxi Province illustrates a business model based on an unbundling of management into business units which trade water, information and money as a basis for on-demand irrigation ordering and delivery based on a pure service-oriented model (Facon, 2010). A practical consideration is where to locate the interface of final delivery from the canal system to an intermediate or farm reservoir. The type and scale of final irrigation distribution systems that farmers have organized to invest in or private operators have developed will provide a useful indication. This unbundling can support the development of clear strategies for financing of management, operation and maintenance and upgrading, with clear interfaces for service and financial transactions. Farmers below the final delivery point may opt for various solutions for final delivery and locating investments in service improvement there while the upper levels focus on more stable bulk water supply may provide conditions for a more dynamic evolution of the systems. There are indeed many options. The MASSCOTE approach recommends moving away from classical PIM/IMT models and creating powerful and professionalized farmer-owned organizations serving large sub-command areas, receiving bulk water supply from the main system and managing canal, groundwater and rainfall. The creation of an institution capable of both managing relations with the bulk water supplier and the sustainability of atomistic irrigation in its command area is an area for future research.

Bringing service delivery in line with water allocation, cost recovery or water charging policies is also an important consideration for modernization. The vast majority of irrigation systems are simply not capable of delivering water on a volumetric basis at any level of delivery in the system. Bringing water control and service delivery to a level where a service specification can be confidently specified, contracted, delivered and evaluated will frequently require significant changes in operation strategies. Any rehabilitation or modernization program should be mindful of present and future plans for cost recovery and contracting of services and select design options that are compatible with the latter. This is frequently not the case (Facon, 2002).

The lack of proper maintenance of irrigation systems and the build-neglect-rehabilitate-neglect-rehabilitate cycles have been the object of much comment and attention, compared with operation, but little effective action.. Efforts to break this cycle by PIM/IMT have generally been unsuccessful and have not generated sufficient resources (Renault et al., 2006). Asset management, a process of assessing the cost of sustaining the physical assets in the context of a chosen (by the user) level of service and a related agreed level of fee payment (Burton et al., 1996) has been introduced as a management tool that can be very effective in a strategic planning process underpinning modernization and service-oriented management that includes medium- and long-term infrastructure and management upgrading processes (Malano et al., 1999). A transparent method for assessing the costs of delivering services is essential in discussions with users and irrigation agency decision makers on adequate levels of financing of maintenance and services fees. Asset management in practice has often been limited to an effort to rationalize and optimize resource allocation between rehabilitation, maintenance and repairs without switching to service orientation. If the context is a rapid evolution of service needs, socio-economic environments and river basins, an exclusive focus on maintenance, which may well be the priority in the short term, can be seen as an effort to solve yesterday's problems rather than addressing tomorrow's needs. There is no reason why farmers should be willing to pay for a service that is grossly inadequate if they have to incur most of the costs to meet their service requirements. Where these costs related to pumping are high, a good question management can ask is: how can we reduce your pumping costs? Farmers' willingness to pay for the irrigation service may increase if this service is improved to the extent that it significantly decreases their pumping costs.

At the end of the day, the major issues may not be so much related, in terms of order of priority, to who pays for what as to what you pay for and to the balance between spending in new construction and maintenance or upgrading of the existing assets[7].

4.2 Is there a space or a need for new large-scale irrigation systems? Will large-scale irrigation systems come to the rescue of atomistic or small-scale irrigation?

Obviously, in closing river basins where water is already over-allocated, there is very little space for new large-scale irrigation systems, the investment in which will go to waste, barring significant inter-basin transfers[8]. So what are the potential new large-scale irrigation development frontiers? In terms of potential, they lie largely in Southeast Asia where there are still in areas with still relatively abundant water and land supplies.

Four main situations can be distinguished. First, development in areas with little present farming or populations. This is the case for Malaysia's Western States and Indonesia's least populated islands. The rationale for both countries is different. For Malaysia, the purpose is to develop rice production in areas with little competition for water. There the proposed model is large-scale highly intensive and mechanized private irrigation systems. For Indonesia, the main purpose would be to relieve the pressure on both land and water in densely populated areas. However, previous "colonisasi" programmes have met with mitigated success and in both cases these programmes are likely to meet resistance on political, environmental and indigenous rights grounds.

Secondly, development in areas with existing traditional agricultural land use and an agrarian type of socio-economic environment. These include Laos, Cambodia, certain areas in the Philippines, Myanmar etc. There, the potential exists (FAO-RAP, 2007) and investment is indeed being planned (Hoanh et al, 2009). Whether large-scale irrigation development is the best option in terms of public policy needs to be assessed carefully and

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7 Many irrigation agencies are currently allocating most of their budgets to expanding their portfolio of assets while the resources to maintain it remain stagnant and insufficient. This gradually exacerbates the underfunding of operation and maintenance.

8 The latter are essentially intended to relieve the pressure on the existing irrigation infrastructure (China, India). Thailand National Water Grid project aims at developing new large-scale irrigation projects in north East Thailand, but with its very high investment and operating costs and questions on why the future developments should be more successful than previous ones under labor shortages and environmental constraints remain open (Hoanh et al, 2010).

thoroughly against other options (FAO-RAP, 2007). The question is redefined with the emergence of new types of investors (Laos (Phouthonesy E., 2010), Cambodia) being granted concessions for large-scale irrigation development (corporations, either private or closely linked with sovereign funds or state interests) or new sources of external financing with few safeguards and conditionalities (Hoanh et al., 2009). Before, Laos had no plans for large-scale irrigation development while for Cambodia, these plans were part of public investment programs (FAO-RAP, 2007). Traditional donors, made cautious by the very mitigated success of previous projects, are reluctant to support these projects. While this does provide opportunities for investment, the lack of transparency surrounding these projects raises issues of social equity and technical, economic and environmental feasibility (Hoanh et al., 2009). Whether these projects will contribute to national food security is based on the assumption that food locally produced will be stored and made available for local consumption in cases of local or national food shortages. But food always finds a way outside national borders to meet higher prices.

Third, development in areas where aquifers are critical and demand management is likely to fail (Shah, 2008), where the objective would be to substitute surface water for groundwater and/or recharge the aquifers: arid alluvial aquifers, where "demand regulation needs to be combined with importation of water to promote conjunctive use through recharging of the aquifers as well as for surface irrigation in lieu of pumping groundwater"; arid alluvial aquifers with acute salinity problems, where "large-scale public interventions on the supply as well as the demand side my help stem the exodus. Where copious fresh surface water is available, the solution to groundwater problems lies in improved management of aquifers"[9].

Finally, large-scale water infrastructure development can be designed to support existing traditional irrigation, blending ancient and new technology, for instance by improving bulk water supply from new large-scale infrastructure to existing traditional systems, as in the Deduru Oya basin in Sri Lanka or in Tamil Nadu (Mukherji et al., 2009).

4.3 Atomistic and small-scale irrigation: direct or indirect interventions? Markets, cost recovery or subsidies? Individual or collective development models?

In the case of small-scale traditional irrigation systems with a household poverty reduction/food security objective in agrarian economies, there seems to be a clear-cut case for direct policy intervention that is at least partly subsidized. This can easily be extended to "atomistic" options such as water harvesting, groundwater recharge, farm ponds, etc. which have a high labor component and which can be paid with wages as part of a social program such as under India's National Rural Employment Guarantee Act (Mukherji et al, 2009). Such support has been found not always to be necessary: India's water harvesting and groundwater recharge movements were initiated without government assistance and only at a later stage supported by state or central government programs. One can replicate these collective dynamics starting from individual initiatives broadening into collective undertakings by carefully designed social mobilization programmes (Shah, 2008).. Amortization (i.e. farmers paying back the development agency for the investment costs) is also an option

[9] For other types of aquifers, the priority would lie not with new large scale development but with further development of the groundwater potential for maximum social welfare (amply recharged humid alluvial), or in building on or initiating water harvesting, recharge and local demand management (hard-rock areas with reasonable rainfall or where water harvesting is already a popular practice) (Shah, 2008).

currently practiced for community irrigation systems in certain countries. Lack of acceptance of this policy, as in the Philippines, is a sure sign that farmers are not interested in buying the type of infrastructure that the Government wants to build or sell to them.

For small-scale and atomistic irrigation options that are essentially dependent on equipment to function, experience from countries that have experienced a boom in these options suggests that initial subsidies may be helpful but that if the option is profitable, the development will quickly supersede the subsidies program which may indeed slow down the adoption of the technology. Market liberalization for the equipment has proven to be a very effective option to trigger the explosion of pumped irrigation (Shah, 2008). Market-based approaches for low-cost irrigation are shown to be useful for those farmers who cannot access subsidies, but entail very high social mobilization and support costs (DFID, 2003). It is suggested that, in order to promote broader dissemination, subsidizing the manufacturing industry by subsidizing the cost of raw materials and letting the private sector sell the products may be more effective than subsidizing the procurement of equipment by users (Shah, 2008). Where private operators are already investing, one possibility is to entice them to invest as intermediate or final operators for water distribution to expand irrigation through water markets. However, specific financing modalities can be developed for those farmers who have no savings and where no suitable rural micro-credit or credit institution can provide the small capital loans to allow them to access the technology (Facon, 2010).

The most powerful support interventions can be indirect or outside the water sector. Where the key constraint is access to markets, linking farmers to markets through technology, farm roads, communications, local market facilities and assisting in their organization to capture a fair share of the value added to market may be they key transformational change: irrigation will follow the new market opportunities. Improving household economics and improved tenure to allow them to save and invest are other such options. Interventions in the energy area in India to manage water demand for groundwater by restructuring the energy grid have proved remarkably effective (Shah, 2008). It is now suggested that rural electrification may be the key single measure to allow further development of untapped groundwater potential in the Gangetic plains (Mukherji et al., 2009) or to take advantage of hydropower development in the Lower Mekong Basin (Johnston et al., 2009).

4.4 Institutional innovations

At the moment, key sources of institutional innovation are, on the informal water economy side, India and, on the formal water economy side, China. The range of spontaneous or autonomous institutions formed by farmers in India is staggering while spontaneous institutional innovations supporting water harvesting or groundwater recharge movements have had a massive effect (Shah, 2008). The private sector has also been very dynamic in the development of atomistic irrigation in the whole of South Asia. New forms of social management of groundwater have also been successfully tested in Andhra Pradesh and are being replicated in other states (Facon, 2010). While many of these models are dependent on local circumstances, this is an area where developers in that sub-region can look for inspiration. Local water markets have a substantial potential to travel, such as, which could be a model for countries planning to develop shallow tubewell or pumped irrigation.

China is also a source of successful innovation for formal institutions. China's reforms of irrigation are based around creating profitable water businesses for the long-term financial sustainability of the project. The country has been largely successful with its 'bounded service provider' model, which aims to create water-saving incentives for water managers[10].

Elsewhere in the region, but also in formal South Asia, the dominant model for institutional innovation has been the standard PIM/IMT model inspired by the Philippines [11]. Its general failure has usually inspired a call for more reform. Efforts to research existing traditional forms of organization have been primarily geared towards their conservation rather than to assess their robustness or adaptability to change or the onslaught of pumped irrigation, seen as a threat by advocates of social capital (not by farmers). Malaysia, confronted with the rapid graying of a narrow farming population, is exploring the concept of "estatization" of water users associations on existing large rice granaries. Farmers retain ownership of land while most farming operations are done by professionals or are contracted out. The future will probably see similar evolutions (extended to the delivery of irrigation services) elsewhere. Or will we see land consolidation with private entities taking over the systems?

An important type of innovation is the crafting of legal instruments geared at achieving demand management objectives by targeting specific technical details. The Punjab Preservation of Sub-soil Water Act-2009 is such an effort to conserve groundwater resource by mandatory shifting of the transplanting of paddy to periods of low evapo-transpiration demands. This resulted in a net water saving of over 2 Billion m3, i.e. a saving of 7 percent in annual groundwater draft, and of about 175 million KWh of energy used for pumping with no loss in rice productivity. (Sharma et al., 2010a).

4.5 Of policy options and the general merits of 'Plan B'

This paper voluntarily refrains from suggesting specific policy options at this point. Various policy options have been discussed in the previous sections. These include successful policies, as well as the difficulties related to importing standard policy prescriptions into a context that does not fit the problem description or where these policies have no chance of being adopted for political reasons. For this reason, this paper prefers to invite policy makers to explore Plan B or second best options, which can actually be very effective, rather than wait (possibly for a very long time) for the Plan A policy option to become feasible. In particular, interventions that significantly improve the situation on the ground for public irrigation managers and water users and cater to the expressed needs of farmers may build in the long run a constituency for policy changes (Facon et al, 2008). This would also lead to a process of policy designed focuins on the importsnt detials that need to be ameliorated or

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[10] Water managers from the local water users association or contract management arrangement receive a basic fee but can increase their incomes by saving water. The lower the village requirement for water, the more they earn. Studies from the Center for Chinese Agricultural Policy and the International Water Management Institute found that water use per hectare is lower in villages with incentivized management of large irrigation schemes by as much as 40 per cent. This saving does not significantly reduce yields of major crops, including rice and maize.

[11] It is actually not always clear that imported models of water users associations have any merit over existing forms of formal organization. For instance, communes in Vietnam do have many problems. However, they employ irrigation teams that distribute water to the field. This would seem like a valuable feature to build on as farmers are increasingly part-time or absentee farmers. Unfortunately, the standard WUA model eradicates this feature. In Cambodia, the WUA model that was adopted is based on a single canal typical irrigation system. However, types of systems are much more diverse and fitting this organizational model to the operational requirements and characteristics of the systems is proving difficult. Meanwhile, traditional management systems can actually prove quite capable of adapting to change, as has been demonstrated for montane systems in Northern Thailand (Shivakoti et al., 2006).

changed, the devil being in the details. These policy options in any case also have to be envisaged within a broader policy context where questions of socio-economic development, food security and environmental sustainability will receive very different answers.

This is not to say that the domain of policy reform is not important. It is. Indeed, having a clear idea of the future policy instruments for water pricing, cost recovery that one wishes to implement is necessary for devising a feasible pathway for the reconfiguring of the irrigation systems so that they may support the level of control, measurement and service that will be required, and enable a progressive formalization of the irrigation water economy by deliberately mobbing towards meeting the farmers' service demand, and avoid investing in operation concepts that will result in dead ends (proportional flow division, Warabandi) or will continue to force farmers to secede from the systems. This paper thus argues for new approaches to design and facilitate policy changes. The IWMI-Tata Water Policy Program of India is a remarkable example of the effectiveness of these new approaches. In China, pragmatic policy experimentation within a broad strategic environment backed by strong policy monitoring and evaluation have been very successful. Tools to better inform planning and policy making are proposed below.

4.6 Revisiting water accounting and policy, investment and financing frameworks

"Integrated approaches" based on managing not just withdrawals but also depletion, on a sound water accounting basis, have become a necessity for critical groundwater systems, areas with significant conjunctive use of surface and groundwater, closing river basins and systems characterized by high return flows (deltas, rice systems) but also areas where improving the productivity of rainfed agriculture is planned (Calder et al., 2007b, Rockstrom et al., 2010). Accurate accounting and measurement of water use can help identify opportunities for water savings, increase water productivity, improve the rationale for water allocation among uses, provide understanding of the impacts of different options, and support better management outcomes. Investing in the deployment of sound water accounting and auditing capacities and supporting information systems is therefore an essential component of and a pre-requisite for any policy or strategy for conservation, reuse and recycling, or investment program that aims at conserving water resources, achieving water savings and water productivity gains in agriculture, or transferring water from agriculture to other sectors. As has been shown above, this is still far from being understood or implemented. Even recently published and actively disseminated guidelines for river basin management still only focus on abstractions and blue water (GWP, 2009) or while they insist on understanding how changes in land use affect the basin's water regime (UNESCO-NARBO, 2009), still do not draw the necessary conclusions. Water accounting still remains, with few exceptions, in the domain of research.

China stands out as the country that has adopted approaches based on beneficial consumption for river basin development planning (World Bank East Tarim Project – World Bank, 2004-2007a) or evapo-transpiration (ET) management to develop and monitor integrated water conservation strategies for critical aquifers[12] (Ministry of Water Resources,

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[12] In Beijing, Hebei, Qingdao and Shenyang, which are areas characterized by aridity, high drought risks and overexploitation of groundwater resources for irrigation, the only solution is to reduce total evapo-transpiration. This Ministry of Water Resources' Water Conservation Project has developed an integrated water conservation strategy based on four innovations: (a) having ET reduction and improving water productivity per unit ET as

PRC, 2007). As modeling costs decrease and data from the field and from remote sensing become easier and cheaper to obtain, there are few technical or economic reasons why water accounting should not become a widely available tool for decision-making. What is required is building the demand for these tools by decision makers, river basin and irrigation management, through awareness and capacity building, monitoring of actual river basin dynamics, and making this information available.

Decisions on investment and financing need to consider a socio-economic context that is highly dynamic and complex, a diverse and changing typology of farmers, irrigation systems and options, differing local circumstances, a diversity of investors, and needs to be more firmly anchored in major socio-economic development objectives and broader policies. This is very different from previous approaches linked to progressive development of an "irrigation potential" based on a rigid model.

FAO has developed a sectoral planning and management tool that fulfills these requirements, called a generic investment framework (Riddell et al., 2008). This tool has already been applied in a number of countries and is being introduced in Asia (Riddell, 2010). An essential component of this planning management tool is a solid monitoring and evaluation system. The tool links sectoral targets to overall socio-economic development targets. As the share of different types of farmers of the sector changes over the short, medium and long term, so do the emphasis in terms of capital assets and the strategic importance in terms of actions to improve the enabling environment. And so do the implications in terms of indicative levels of public and private cost allocation for capital investment and recurring costs between government capital (all sources, including river basin organizations), water users (beneficiaries) and the private sector. The development and management of these generic investment frameworks can be of great help in thinking about questions such as the strategic importance of investment in different types of irrigation systems (atomistic, small scale, large-scale) over time, developing realistic evolution scenarios for different types of irrigation systems over time in response to changes in the structure of the sector and future policy instruments and regulation of the sector, preparing for realistic financial planning over time, and identifying and pipelining adequate measures to improve the enabling environment and institutions that will reflect the objectives and nature of the different actors.

5. Conclusions

The explosion of atomistic irrigation in this region has significantly widened the gap between official irrigation and river basin management discourse and structures, and on-the-ground irrigation and river basin realities. As river basins close, groundwater is overdrawn, environmental impacts worsen and energy prices soar, it is urgent to acknowledge the new reality that has emerged and anticipate its future evolution. It is critical that the benefits of the atomistic irrigation explosion be appreciated, and this must occur in parallel with an acknowledgement of its sustainability crisis. To a large extent, the dichotomy between small-

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explicit objectives and operational targets; (b) improving infrastructure and operation to improve productivity and incomes; (c) developing institutions, allocation mechanisms and supporting information management systems to sustainably manage groundwater; and (d) establishing a water supply organization and water users associations, forming a complete self-management irrigation and drainage district system.

scale and large-scale irrigation has become redundant, but is still useful in areas where expansion of irrigation is possible. In any case the different types of irrigation systems have to be considered in terms of how they support the needs of different types of farmers.

This phenomenon, however, has also highlighted the fact that, far from being passive recipients of official irrigation development and management, farmers have an enormous capacity for innovation, investment and supporting the costs of irrigation service delivery, as long as this is the service that they need and irrigation is a profitable proposition. How to unleash this potential and work towards meeting their service needs is the essence of the challenge facing tomorrow's irrigation.

Demography, market pull, water constraints and energy but also the emergence of a new class of increasingly educated and assertive farmers will largely determine the mix of atomistic, small-scale and large-scale irrigation and their evolution and relative expansion or decline over time in different river basins and socio-economic environments. The closing of river basins in the regions will limit the scope for the expansion of both large-scale, traditional small-scale and atomistic irrigation. The main focus will have to be on improving the performance and productivity of existing irrigation systems and the paper elaborates on strategies and tactics to do so for large-scale irrigation systems. In areas where expansion of irrigation is still possible, the paper discusses best bets and enabling strategies in the different sub-regions.

We must move from a situation of competition and conflict between atomistic, small-scale and large-scale irrigation to a fluid logic of complementarily, combination and convergence. Moving towards this goal requires first of all a change of perspective and of the framework in which decisions are assessed and made. This paper will be interpreted by some as proposing an 'alternative' view of agricultural water management: a central argument is certainly that in many cases the 'virtual reality' of imported frameworks, official agency outlooks and descriptions of the sectors and the river basins needs to be reformed, together with the institutional structures and programmes that embody them.

If this happens, it can greatly enhance the mobilization of resources from the public sector, the private sector and water users and result in significant payoffs, positive outcomes and more sustainable results. Adopting a fresh perspective may assist in finding new solutions to old problems that have long undermined the sector, such as poor maintenance and financial sustainability. While the classical recommendations, such as those commonly associated with IWRM, become increasingly relevant in formal and transition water economies, this does not mean that they can easily or should necessarily be followed. In any case, having a clear short, medium and long-term perspective on future policy instruments, service requirements and water-related performance targets should inform decisions on the details of design, management structures and operation strategies of current investments and on planning for their progressive modernization.

The IWMI-FAO-ADB Revitalizing Asia's Irrigation study has proposed five key strategies to move forward that provide clear directions for future interventions in the sector. This paper has further elaborated on the rationale for these five strategies and discussed options, details of strategy and tactics:

1. Modernize yesteryear's schemes for tomorrow's needs (reconfiguring irrigation systems);

2. Go with the flow by supporting farmers' initiatives (reconfiguring irrigation systems, moving towards conjunctive management strategies, institutional innovations, supporting an enabling environment, coping with sustainability issues)
3. Look beyond conventional PIM/IMT recipes (reconfiguring irrigation systems, institutional innovations, unleashing the investment potential, need for structural reform)
4. Empower all stakeholders through knowledge (capacity building, water accounting and innovative planning tools)
5. Invest outside the irrigation sector (enabling environment, energy sector interventions)

A considerable body of knowledge does exist on how to support these strategies, transform large-scale irrigation systems and promote various forms of atomistic, small-scale and large-scale irrigation systems. Tools have been proposed that support long-term sectoral planning and management for future investment and the design of measures to support an enabling environment. Planning and policy mechanisms will require looking outside the irrigation or water sectors narrowly defined and this is often where effective interventions will be found.

Obstacles to changing the outlook of the sector, which are required to change decision-making on future investments in the sector cannot be underestimated, but as shown in examples illustrated in this paper, this can be done. Experience has shown that policy and reform imposed from outside have not live up to expectations, and international financial assistance's capacity to impose them will continue to erode in the region. Capacity building and changing practice and results on the ground, together with the adoption of robust monitoring and evaluation systems for investment and policy results, can serve as a basis for developing a broad constituency to effect the changes in governance and policy and the fundamental sectoral reforms that are needed (Facon et al., 2008) This will have to be supported by an overall reform of the educational establishments and of their curricula, for new generations of decision makers, experts, consultants, managers, operators and farmers to be equipped with new concepts and knowledge to embrace, support and implement a change agenda. This change agenda needs to be clarified now, to ensure that present opportunities for investment actually contribute to making this change agenda possible, rather than more difficult.

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