Challenges and Developments in Financing Irrigation and Drainage Sector[1]

Uma Lele, Tushaar Shah, Mohamed Ait Kadi, Herve Plusquellec, Richard Reidinger[2]

[1] A Keynote Paper prepared for the Plenary session on sub theme *2: Challenges and Developments in Financing Irrigation and Drainage Sector ",* of the ICID First World Irrigation Forum, Mardin, Turkey, and September 2013.

[2] Uma Lele, independent scholar and former Senior Advisor at the World Bank and Tushaar Shah, Senior Fellow at the International Water Management Institute, Colombo, are members of the Technical Committee of the Global Water Partnership, Mohamed Ait Kadi is President of the General Council of Agricultural Development and Chair of the GWP Technical Committee, Herve Plusquellec and Richard Reidinger were respectively the former World Bank Irrigation Advisor and Lead Agricultural Economist in the World Bank's Asia and Pacific Region. We are grateful to Daniel Gustafson, Ren Wang and Josef Schmidhuber at FAO, John Metzger at GWP, Jacob Burke at the World Bank and Oscar De Moraes Cordeiro Netto is the President of the National Water Master Plan Commission (CTPNRH) and President of the Brazilian Water Resources Council (CNRH) for their critical comments and contributions of data and information during the earlier drafts of this paper, and to Sambuddha Goswami and Julia Schaefer for research assistance. This paper reflects the views of the authors alone and do not reflect the views of any of the organizations with which the authors are currently or were formerly associated, nor of all those who commented on the paper.

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" I only hope that (my failure to speak out three decades ago) will encourage others to be bolder so that policies and practice can be better grounded in realities and ………. offset the professional, institutional and personal forces that so easily distort perceptions and generate and sustain misleading and damaging myths. We need not just to struggle to know reality. We need whistleblowers. And we need them to blow more and a good deal louder than I did"-- Robert Chambers

Uma Lele, Tushaar Shah, Mohamed Ait Kadi, Herve Plusquellec, Richard Reidinger[4]

Abstract

Now is a critical time to examine developments and challenges in financing irrigation and drainage in the wake of the post 2007 period of rising food prices, and a renewed focus on global food security. This paper stresses that agricultural intensification is the key to improved food security. Water is critical to intensification. Increasing water use efficiency and water productivity are both of utmost importance to meet future food needs and efficiency increase in the water sector must be achieved in the context of increasing total factor productivity. To increase water efficiency and water productivity financing of irrigation and drainage needs new paradigms For example, surface irrigation needs to be modernized not just rehabilitated with more construction. Rehabilitation may be necessary but will not be sufficient and must be seen as part of modernization with focus on improving main system management, reforming irrigation institutions, capacity building and realigning incentivesYet modernization is not a silver bullet. Modernization cannot be copied blindly Modernization must be contextual due to the immense diversity among regions and countries and within countries. That means differentiated and textured strategy for irrigation and drainage investments according to a level of economic development. Concerns in Malaysia are very different from Pakistan and both are different from China and Uzbekistan. Modernization needs innovation, adaptation, monitoring, evaluation and dissemination. Service delivery to clients must be at the center stage. Not only the quality of service to farmers must be improved but the capacity of national institutions to deal with complexity in the context of rapid change in irrigation and other technological changes must get high priority.

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The paper explores the role of irrigation and drainage in the context of the world food supply and demand and expanding world food trade. Since the early 1990s accelerated economic growth throughout the developing world has increased demand for food, helped boost food production and trade until 2008 when the great recession slowed economic growth, and rising food prices led to ban on food imports and exports of major trading developing countries. Fortunately the bans turned out to be temporary as soon as "normalcy" was restored. And yet the food and financial crises are a wake-up call. Financing for irrigation and drainage needs to become a part of sound agricultural water management and food and agricultural development strategy generally, in turn both contributing to environmentally sustainable and equitable economic growth in developing countries. The paper outlines why now irrigation and drainage financing must be seen in a completely changed context, and yet, why we must draw lessons from the vast experience with past irrigation and drainage investments keeping farmers at the center stage as the clients. The paper ends by drawing implications of the experience going forward.

Introduction

When in the early 1970s prices took a sharp upturn, international donors and national governments greatly increased investment in irrigation, mainly in Asia as part of the expansion of overall investments in food and agriculture. These investments were accompanied by the establishment of the CGIAR, with a center especially created with a focus on irrigation and drainage, now renamed as the International Water Management Institute. The international investments were accompanied by investments in the national agricultural research and educational systems and in service delivery, leading to steady increase in agricultural productivity growth. The Green Revolution which the investments in Asia generated also created substantial employment and incomes for the poor both directly in agriculture and indirectly through a decline in food prices until 2007. Whereas the increase in investments – public and private - were the foundation of the Green Revolution in India, Pakistan, and in much of the rest of Asia, irrigated agriculture also expanded in developed countries. Latin America and Sub-Saharan Africa with large expanses of land and relatively little population pressure remained largely rain fed. As developed countries remained major sources of food surpluses and food aid, fueled by agricultural subsidies, Latin America emerged as a major exporter of food and agricultural products to the world. Yet nearly a billion people remain hungry and almost all of them are in Asia, broadly defined to include the Middle East, and in Sub-Saharan Africa.

In short whereas irrigated agriculture has dominated most of Asia-and nearly two thirds of the world's irrigated areas are in Asia, productivity of rainfed agriculture in Asia has been largely neglected. Besides rainfed agriculture in Latin America and Sub-Saharan Africa can bring considerable amount of land potentially under cultivation including under irrigation. This will be particularly so if Asia and Sub-Saharan Africa fail to intensify their agriculture, to feed the hungry and meet the burgeoning food demand, and if world food prices rise, creating stimulus for area expansion and adversely affect the environment through the loss of forests and biodiversity throughout the world. Besides since Africa is at an early stage of development it can learn a great deal from the experience of Asian Countries on sound exploitation of water resources by getting it right from the start.

Today's Different and More Complex Challenges for the Financing of Irrigation and Drainage Requiring A True Integrated Water Management Approach for Sustainable Water Management

The current challenges are quite different and more complex than in the 1970s. FAO estimates that between 60 to 90 percent of water is used in agriculture, depending on the country. So some challenges are prompted by the second generation problems the Green Revolution created, others are a result of a radical change in the "external" global environment. Irrigation and drainage investments today must be seen in such a wider perspective. Water management must go beyond the debates pro and against irrigated agriculture and pro and against dams (Winpenny 2003). This paper takes the view that agricultural intensification and improved water use efficiency must been seen as part of increase in total factor productivity of agriculture as a whole and not in isolation. Water is a finite and an increasingly scarce resource in many parts of the developing world including particularly in Asia. The more water the agricultural sector uses, maintaining old water using patterns of consumption, and food and water waste remain, the less water is available for the growing household consumption, and urban and industrial uses. At the same time conjunctive use of water has reached unsustainable levels in many parts of Asia and food consumption patterns are changing rapidly in Asia, rice consumption growth has slowed and improved agricultural practices including satellite imagery, precision agriculture, information and irrigation technologies such drip and sprinkler systems offer tremendous opportunities to reign in water use with a razor sharp focus on water use efficiency and total factor productivity in agriculture. This call for astute public policy, going beyond building dams, since with the new technology Jevons paradox can begin to operate, increased private efficiency leading to greater incentives to invest in water, leading to over-exploitation. Hence whereas eclectic location and situation specific approaches are needed drawing on global experience, public policy is of increasing importance. Water management must be seen as part of overall investments in the agricultural and the rural sector, including in energy development and efficiency, and not separately from it. Besides we now know a great deal more both about policies and institutions and technologies for water saving and management that work than when the initial investments in irrigation and dams were made so that investment choices in the irrigation and drainage sector must be based on settling old technical debates, albeit in the context of socio-economic objectives. This must mean using multi-disciplinary, multi-sectorial empirical analysis of the experience to date, so that knowledge informs improvement in investment quality as well as quantity of irrigation and drainage services. The new contexts we must consider include the following:

First, rapid economic growth, population growth and urbanization have increased domestic inter-sectorial competition for land and water with growing water shortages across sectors..

Second, technological change has been very rapid in some areas particularly in information and communication technology, satellite imagery, new adaptable, flexible irrigation systems. And there is a boom in private investment in irrigation throughout South, South-East and East Asia. But these developments pose complex challenges of reconciling flexibility and private profit with collective good of managing natural resources sustainably. This means a complex, more sophisticated role for cooperative strategies involving governments, communities and a socially responsible private sector. It means governments going beyond simply building more dams.

Third, improving data quality is of highest priority for sound water management. Governments and their citizens have the primary responsibility for generating good data. Without good data sound planning and investment is impossible. Just- in -time collection and timely dissemination of data to the citizenry at large and to policy makers on a routine basis can greatly improve governance of natural resources. Reduced rates of deforestation in Brazil based on dissemination and use of just in time deforestation data as an input to public policy offer an inspiring example of collective action among Federal and state governments, NGOs, environmental think tanks, universities and the private sector (Lele et al 2013a). Governments acknowledge that quality and reliability of data on water resources and uses leaves much to be desired, and yet investment in water data remains one of the most neglected areas. Working with governments, donors and other international organizations, the Food and Agriculture Organization of the United Nations (FAO) has embarked on a major new initiative to improve agricultural statistics with a broad scope. The World Bank has initiated a global coalition for natural resource accounting as part of the gross national product statistics. All stakeholders should support these efforts.

Fourth, with globalization the world is far more vulnerable to external shocks and to spikes in food prices than it was previously. The world population and income growth have pushed up demand. The Organization for Economic Co-operation and Development (OECD) countries has been reducing agricultural subsidies, their surpluses and stocks. International trade in food and agriculture has expanded, and food aid has virtually vanished. The former reflects economic growth in developing countries and the latter declined surpluses and stocks in OECD countries. Rising food (and energy) prices have caused street riots leading governments to pursue autarkic policies of domestic food self-sufficiency. The ability to trade food freely and predictability will critically influence domestic incentives for food and agriculture including investments in irrigation and drainage.

Fifth, increased international competition for land and water has increased international land purchases particularly in Africa popularly known as the "land grab". Whereas there is little reliable information on these land purchases, those purchases have increased vulnerability of the land dependent populations globally, particularly in Africa. FAO's landmark Voluntary Guidelines on the Responsible Governance of Tenure signed by all member countries in 2011 is an important development to increase transparency and fairness of international land purchases, but its effective implementation remains to be seen. Sustainable use of water resources should become a part of management.

Sixth, the emergence of biofuels has major, unknown implications for food production, irrigated agriculture and land use. Production of biofuels has been promoted using a combination of pricing, subsidy and energy policies of industrial countries. Furthermore technological change in biofuel technologies has been equally compelling. A third of the internationally traded maize, most produced under irrigation, is diverted to biofuel production. Each poses unknown challenges for future land use depending on relative returns to traditional agriculture compared to biofuel production. Biofuels have also increased the opportunity cost of land and water in developing countries, including for land previously considered degraded and of little value. When combined with mobility of international capital and energy demand, biofuel production possibilities in both advanced and developing countries will influence the economics of investment in irrigation. Energy demand is more income elastic than demand for food. Therefore in a context of accelerated economic growth in developing countries, the impacts of biofuels on land use changes could well be more profound than those from increasing demand for food alone (Hertel 2012; and Wright 2012).

Seventh, the growing land set aside for payment for environmental services (PES) programs is needed for ecosystem functions critical for environmental sustainability including of watersheds. On the one hand PES schemes pose competition for land use in agriculture. The growing popularity of PES schemes is noteworthy in middle income countries with a large urban middle class. Urban consumers in China, Mexico, Brazil or Costa Rica are financing PES programs through taxes. Investment in irrigation—whether large scale or small scale, may have diminishing returns unless ecosystem functions of watersheds are protected, as rivers run dry and ground water is exhausted. These costs should be factored into watershed developments.

Eighth, policies and technology choices in the water sector, including the new water saving technologies, the domestic pricing and subsidy policies towards water, food and energy specifically favoring agriculture are often at the heart of excessive production of water using crops directly, and indirectly through Jevon's paradox.[5] They need more sophisticated multi-sectorial analysis for policymaking. The policy and institutional implications of these rapid technological changes have received less

[5] Resource saving technologies and efficiency associated with them results in increased incentives to use more of the resource.

attention than the attention devoted to physical infrastructure in irrigation and drainage or water and sanitation.

Finally, climate change is a profound game changer. Through a combination of changed hydrological cycles, warmer temperatures, extreme weather extremes, floods and droughts, and increased incidence of pests and diseases, climate change has increased risk and uncertainty in food and agricultural production systems. Estimates of the likely impacts of climate change on agriculture range widely. Increasing resilience and stability of agricultural production to the increasing climate risks is of highest priority. Clearly irrigation and drainage can play a critical role in increasing stability and resilience, provided the design of those investments takes into account climate change impacts, and adaptation and mitigation needs are made with the greatest sensitivity to whole landscapes.

These long term issues related to demand for and the supply of food go beyond the normal concerns for irrigation and drainage but will directly affect irrigation and drainage strategies (Table 1).

Table 1: Long Term Global Food Challenge	
9 Billion+ in 2050: Cereal Production (Net of Biofuels) Increase by 60 percent over 2005 level to meet demand growth of 1.1 percent annually down from 2.2 percent in the past 4 decades • Cereals production must increase by 940 million tonnes to reach 3 billion tonnes; • Meat production must increase by 196 million tonnes to reach 455 million tonnes; and • Oil crops must increase by 133 million tonnes to reach 282 million tonnes.	
On Demand Side	**On Supply Side**
Population Growth --All in LDCs	**Slowing Yield Growth**
Income Growth --Mostly in LDCs	**Climate Change**
Urbanization --Up from 50 percent to 70 percent	**Limits to Land, Water, Soils, Biodiversity, Forests, Fisheries**
Shift in Food Consumption Patterns --Rice, Wheat, Maize, Soybeans for Feed	**Last Frontiers?** ---LAC, SSA, Eastern Europe
Biofuels --Maize, Oilseeds	**Increased Market Related Risks and Uncertainty**
Processed Foods	**DE capitalization of Agriculture** --Investment in R and D

Source: Lele, Agarwal and Goswami, AAEA 2011.

To feed the world population of 9 billion by 2050[6] an estimated one billion tons of cereals and 200 million extra tons of livestock products will need to be produced annually (Alexandratos and Bruinsma 2012). The need for such agricultural growth is the strongest in developing countries, to ensure access of nearly 1 billion undernourished people to food, improve nutrition, increase rural incomes and reduce poverty. FAO projects that one person in twenty still risks being undernourished – equivalent to 370 million hungry people, most of whom will, once again be in Africa and Asia.

Although agriculture must be an engine of growth, vital to economic development, environmental services and central to rural poverty reduction, this centrality of agriculture for development is doubted by many policy makers in developing countries, who see agriculture as a declining sector. In influential donor circles too surprisingly some question the importance of agriculture (Dercon 2013). Therefore continued investments in agriculture cannot be taken for granted.

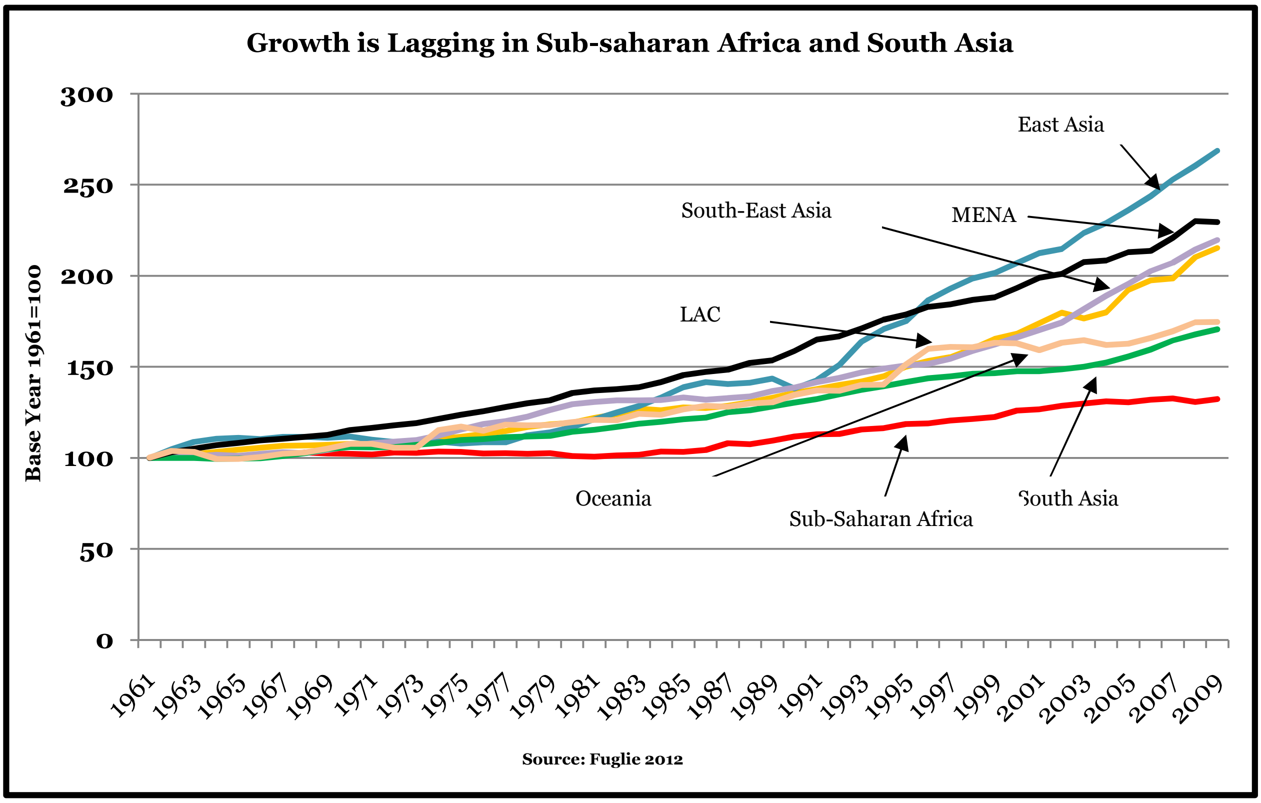
Slowing Yield Growth and Yet Rising Total Factor Productivity

Average rates of growth in agricultural production as well as yields per hectare of major crops have been slowing to 1.5 percent from the 3 percent annual rate of growth. Yet there is growing difference among regions of the world in total agricultural factor productivity (Figure 1). According to Fuglie the largest growth in productivity has occurred in the East Asia followed by Middle-East and North Africa (MENA) region, a region with considerable water scarcity and yet where some examples of high standards of water management can be found, as in Morocco, discussed later in the paper. The MENA region is followed by South-East Asia, Latin America and Oceania. Despite being the cradle of the Green Revolution, South Asia has been lagging behind other regions only to be followed by Sub-Saharan Africa, where reliance on irrigation is limited, agricultural productivity growth is the slowest.

Investment in irrigation and water use efficiency, among other factors, has had a lot to do with these TFP growth rates.

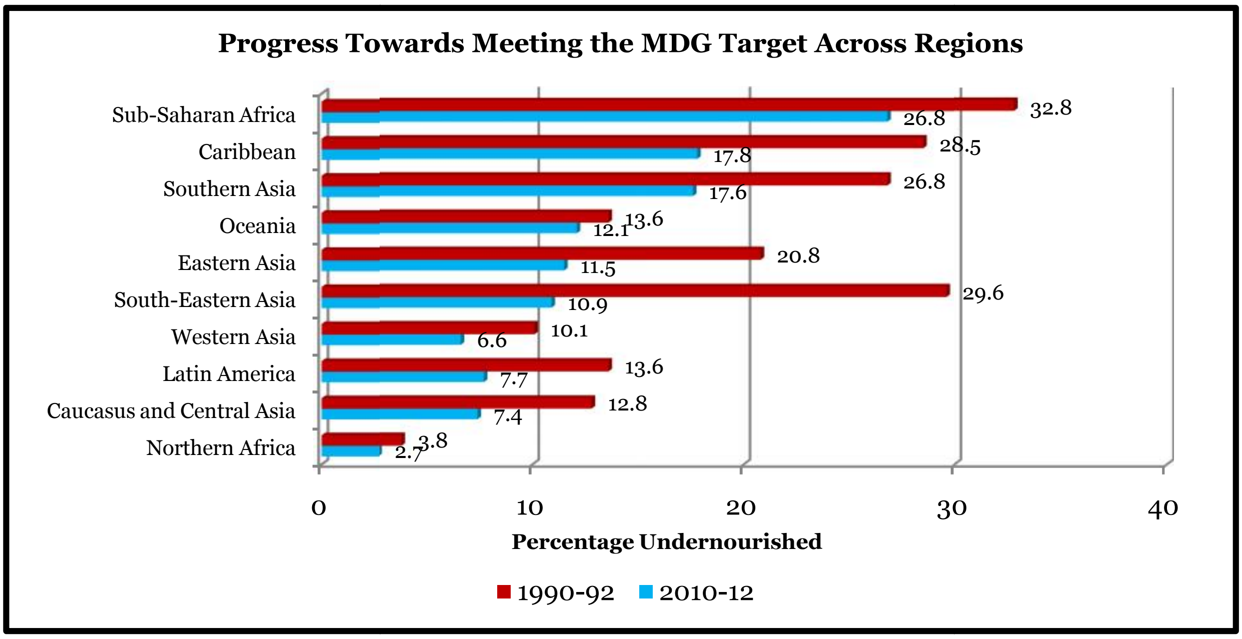
[6] United Nations Population Division Department of Economic and Social Affairs (UN DESA). http://www.un.org/en/development/desa/population/.

Figure 1: Agricultural Total Factor Productivity (TFP) Index Growth by Region (1961-2009)



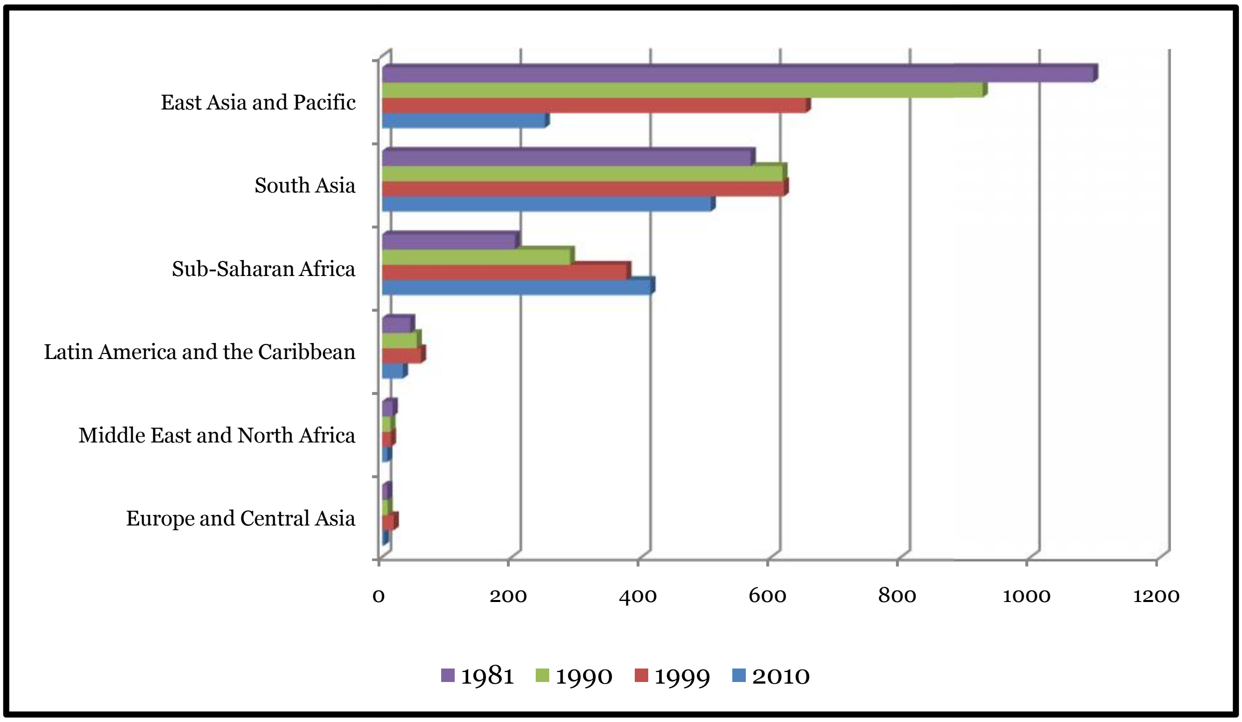
South Asia and Sub-Saharan Africa are the two regions with the greatest incidence of poverty and hunger and indeed their share in the total incidence of hunger has increased over time as other regions, have made rapid strides in reduction in poverty and hunger, e.g. in East and South East Asia (Figure 2 and 3). This is in part because the total factor productivity in agriculture in these regions has been increasing rapidly including water productivity.

Figure 2: Progress Towards Meeting Millennium Development Goal (MDG) 1 Target of Reducing Poverty and Hunger by Half has been Slowest in the Areas of Greatest Incidence of Poverty



Source: FAO 2012b and FAO Hunger Portal.

Figure 3: Number of Poor (Millions) by Region (using 2005 PPP and $1.25/day poverty line) (1981-2010)



Source: PovcalNet: http://iresearch.worldbank.org/PovcalNet/index.htm.

In Search of Smart Solutions

The 2030 Water Resources Group, an alliance of private sector organizations, concluded that historic rates of supply expansion and efficiency improvement will only close 20 percent of the supply–demand gap (2030 Water Resources Group 2009). Future 'water gap' can be closed only if water scarce countries boost efficiency, augment supply, or reduce the water-intensity of their economies by ranking alternative investments in terms of their benefits and costs. We highlight quite a different farmer driven approach to water management. Some countries, including China, the state of Gujarat in India, and Morocco, appear to have made gains in water use efficiency at scale, placing the farmer at the center stage, and yet under quite diverse circumstances. We believe, lessons can be learnt and adapted from their experience with demonstrable impacts on the ground, and at scale, if there is political will, and capacity among a wide range of stakeholders and institutions to adapt solutions to their circumstances, notwithstanding differences in political, economic and environmental conditions in these countries. But clearly lessons cannot be replicated blindly.

Political will and domestic capacity are critical because water and food security pose a 'wicked challenge'. Water is by far the most complex of public or a common pool goods because it has no physical or administrative boundaries. A complex mix of hydrology, engineering, constitutional, legal, political, social, inter-sector, institutional, and agronomic issues – with a mix of vested interests – drive policy and determine outcomes in each country. Its management requires strong interlinked nested solutions involving a mix of private and collective action. It can be possible by an appropriate country and location specific mix of policies, institutions, technologies and incentives. The solutions need to be mutually supportive at all levels; i.e., from the local to the sub-regional and regional and at time transboundary. And yet so far there are few well documented examples of sustainable use of land and water resources in developing countries even after nearly 20 years of global acceptance of the Dublin principles.

Irrigation: The Global Scene

Role of Water Storage

Water storage per capita is a commonly used indicator of water infrastructure availability. It only reveals part of the story since it does not take into account climatic variability nor the water storage capacities provide by nature, for example via groundwater or wetlands. The Seasonal Storage Index, developed by Brown and Lall (2006) provides corrections for some of these shortcomings by taking into account the seasonal and inter-annual rainfall variability. When compared to actual storage, this indicator provides a picture showing which countries have the largest storage gap (Table 2) and which countries most need water infrastructure (the hard option) to manage variability in time and space and to adapt to climate change.

Table 2: Seasonal Storage Index (SSI) and Current Surface Storage as a Percentage of SSI

	Seasonal Storage Index (km^3)	Current Surface Storage as % of SSI		Seasonal Storage Index (km^3)	Current Surface Storage as % of SSI
Burundi	2.64	0%	Senegal	22.3	7%
Malawi	18.98	0%	Ethiopia	40.99	8%
Rwanda	1.38	0%	Albania	2.64	21%
Sierra Leone	2.21	0%	Bangladesh	62.28	33%
Guinea-Bissau	2.48	0%	Guinea	3.71	51%
The Gambia	2.14	0%	Swaziland	0.98	59%
Nepal	29.86	0%	El Salvador	5.45	59%
Haiti	3.73	0%	Mauritania	1.34	66%
Bhutan	0.4	0%	Tanzania	5.5	76%
North Korea	23.32	0%	India	356.6	76%
Eritrea	2.75	3%	Algeria	6.6	91%
Vietnam	27.64	3%			

Note: The Seasonal Storage Index (SSI) gauges the volume of storage needed to satisfy water demand based on the average seasonal rainfall cycle. Calculating current surface storage as a percentage of the SSI reveals those countries most in need of infrastructure to ensure water availability for growing food and meeting other critical needs. (For a more complete list see original source). Source: Brown and Lall 2006.

Box 1: Four Ways of Storing Water have Implications for Financing

Water is stored (1) in the soil profile, (2) in underground aquifers, (3) in small reservoirs, and (4) in large reservoirs behind large dams with advantages and disadvantages to the various levels of water storage (IWMI 2000).

Groundwater Storage

Advantages: Its advantage is little evaporation loss, available on demand, operational efficiency, water quality.

Limitations: slow recharge rate, groundwater contamination (and hence water quality), cost of extraction.

Key Issues: declining water levels, rising water levels, management, groundwater salinization, groundwater pollution.

Small Surface Water Reservoirs

Advantages: ease of operation, multiple uses, responsive to rainfall, groundwater recharge.

Limitations: high evaporation loss, relatively high unit costs, absence of over-year storage.

Key Issues: sedimentation, adequate design, dam safety, environmental impacts.

Large Dam Reservoirs

Advantages: large and reliable yield, carry-over capacity, low cost per m3 of water stored, multipurpose, flood control and hydropower capacity, groundwater recharge.

Limitations: complexity of operations, sitting (location), high initial investment cost, and time needed to plan and construct.

Key Issues: social and environmental impacts, sedimentation, dam safety.

In medium and large scale public irrigation systems, delivery of the water demanded by farmers on time should be the objective of irrigation. This cannot be achieved in projects depending on uncontrolled water supply such as run-of-river projects- and in systems designed to spread the water as thinly as possible, as in the Indian sub-continent which explains the attraction for groundwater.

The critical issue facing many groundwater aquifers today is that the volume of water withdrawal exceeds long-term recharge, resulting in rapidly declining groundwater levels in many areas. IWMI (2000) notes "Small reservoirs have the advantage of being operationally efficient. They are flexible, close to the point of use, and require relatively few parties for management" still, they have a limited storage capacity. "Large surface water reservoirs have the advantage of greater yield relative to the available inflow than small reservoirs, and their yield is generally more reliable."

Combinations of small and large storage and surface water and groundwater recharge are generally the best systems where they are feasible.

Irrigation's Critical Role in the Global Food Production

Overall, irrigation produces a substantial share of the world's grain supply and is important for future food security. Estimates of area irrigated depend heavily on the quality of country data. These vary widely and several countries have acknowledged that billions of dollars have been committed to water management by developing countries and donors without investing in quality, reliable and timely availability of data (Shah and Lele 2011).

FAO's are the only macro-accounts of irrigated production available on a global scale. Accuracy of agricultural statistics on irrigation and drainage are a bigger challenge than statistics on land or forests because of the very nature of water. Countries with mixed rain fed/irrigated production are challenged to report statistics accurately. FAO is working with developing countries to partition rain fed and irrigated crop by crop and periodically reports updates when the data collection or reporting methods improve with improved technology and training. FAO's major new initiative to improve the quality of overall agricultural statistics working with countries, international partners and academics should help provided all support it.

Investment in Irrigation and Drainage (I&D) is also hard to track. For instance, agriculture public expenditure reviews in many developing countries are hampered by inconsistent provincial/state level data. This is equally true for private sector investment in agriculture. Surveys such as the Living Standards Measurement Study (LSMS) may help for some smallholder investments, but capturing the agri-business inputs at country level is difficult unless there is transparency and concerned ministries compile accounts. Hence all data should be treated with caution.

Finally unless there is some definition and agreement on the level of water service required by farmers, which is location specific, hydraulic operations and I&D institutions cannot work. Increasingly water practitioners consider a shift to service-oriented management essential as part of a process of modernization of irrigated agriculture. Farmers would not invest in modern farming practices and in water saving techniques if the water service is not reliable

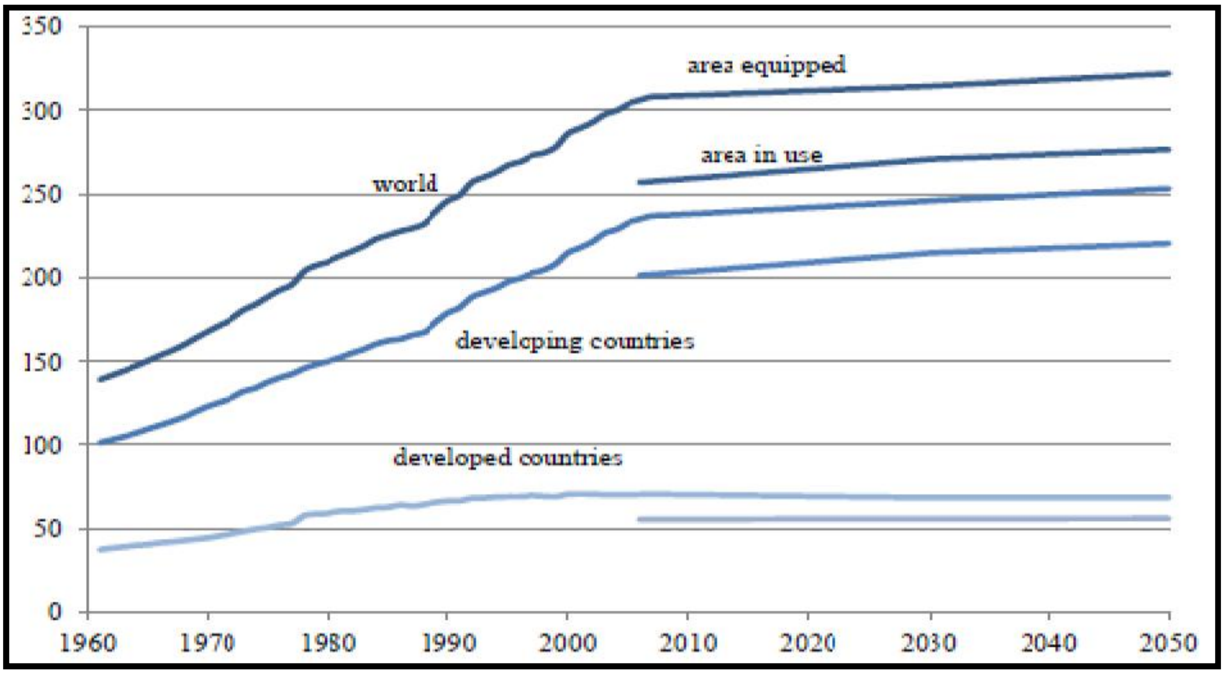
In developing countries many large surface irrigation systems critical for food production suffer from poor or outdated design and engineering and inadequate O&M. Rehabilitation of existing surface irrigation systems will certainly need to be done, often because of both inadequate design and O&M in many LDC systems, just to maintain their current production. But whereas rehabilitation is necessary it is not sufficient. Modernization of existing irrigation systems is needed to increase water efficiency and productivity and in particular to meet the water supply timing, quantity and flexibility needed for highly productive food production in the water-short future. Modernization is defined as a process of improving resource (labor, water, economic and /or environmental) utilization by upgrading (as opposed to mere rehabilitation) the hardware and software in irrigation projects while improving water delivery service to users (Facon 1997). The focus is on improving the quality of service to users. A strict engineering understanding of the term modernization in irrigation would be the level of adoption of the recent technologies (canal lining using geo-membranes, Information Technology (IT) for water control, Supervisory Control and Data Acquisition (SCADA), conversion to pressurized systems etc.). Modern engineering design and digital technology offer many proven avenues to improve water control throughout the systems and to make them more responsive to farmer needs, which is critical for improving efficiency and productivity. Rehabilitation and modernization should be done together as a package where possible and feasible both to correct past deficiencies and to enable those systems to meet the water timing, quantity and flexibility needs of the farmers now and in the future. Modernization should include both hardware and software, designed and implemented together, to help correct deficiencies in main system management and water control as well as in water distribution, including for example, the development of farmer-managed water user associations and entrepreneurs as in China. Substantial financing will be required for irrigation rehabilitation and modernization. In many cases the incremental cost of modernization will likely be relatively small compared to rehabilitation only, but in fact may be the key to whether those investments prove to be viable in practice.

Defining where the public interest in supplying public goods (canal operations, aquifer management) stops and the private interest in irrigation and subsequent value chains (and subsidy support) for irrigated produce starts would seem to be fundamental in setting boundary conditions for public and private investment.

Globally reported area under irrigation expanded steadily since the 1960s, particularly in developing countries. In contrast between 2005 and 2050 FAO estimates an increase of only 6.6 percent of irrigated lands or only 32 million ha in developing countries of which 20 million ha will occur in China and India alone. With 37 percent of the global population and 42 percent of the global irrigated area, outcomes in these two mega countries will have global consequences.

FAO estimates and projections of arable and irrigated land (equipped for the future and currently in use), indicate that that there is more area equipped for irrigation than is actually in use. This is due in part to areas going out of cultivation due to land degradation, desertification, urbanization, salinization, etc. However, perhaps more important are that many large surface systems as designed could not meet the efficiency assumptions contemplated or irrigate their full command area, as for example, in North India, or were never fully completed as with many local irrigation distribution systems in China. Clearly better overall land and water management is needed to close this gap. More specifically, however, such systems as above offer substantial potential if they can be made more efficient and fully completed, as a very large sunk cost investment is already in place.

Figure 4: Arable Irrigated Land: Equipped and in Use (million ha) (1960-2050)



Source: Alexandratos and Bruinsma 2012.

Regional Actual and Projected Growth in Irrigation

The biggest absolute amount of past growth in irrigated area has been in South Asia followed by East Asia (Figures 5a, 5b and 5c). The biggest shares of irrigation in the world are in South Asia and East and South-East Asia together amounting to 75 percent of the irrigated areas in developing countries during 2005-2007 and 57 percent of the world areas (Figure 5d).

The biggest future projected growth in area irrigated according to FAO will be in Sub-Saharan Africa and Latin America (Figure 5c and 5e), albeit from a small base. Although the expansion will slow, particularly in South Asia, and East and South East Asia, the sheer magnitude of their current irrigated areas (191 million hectares in 2011) in developing country share is so large that they receive more attention in our presentation. Besides given that the most dynamic economic growth, large population bases and changed diets etc. will take place in Asia, lessons from Asia are highly significant for Africa going forward where population growth will continue well into the century and food demand will grow rapidly even after it has peaked in Asia.

Figure 5a: Total Area Equipped for Irrigation by Region (1000 ha) (1961-2011)

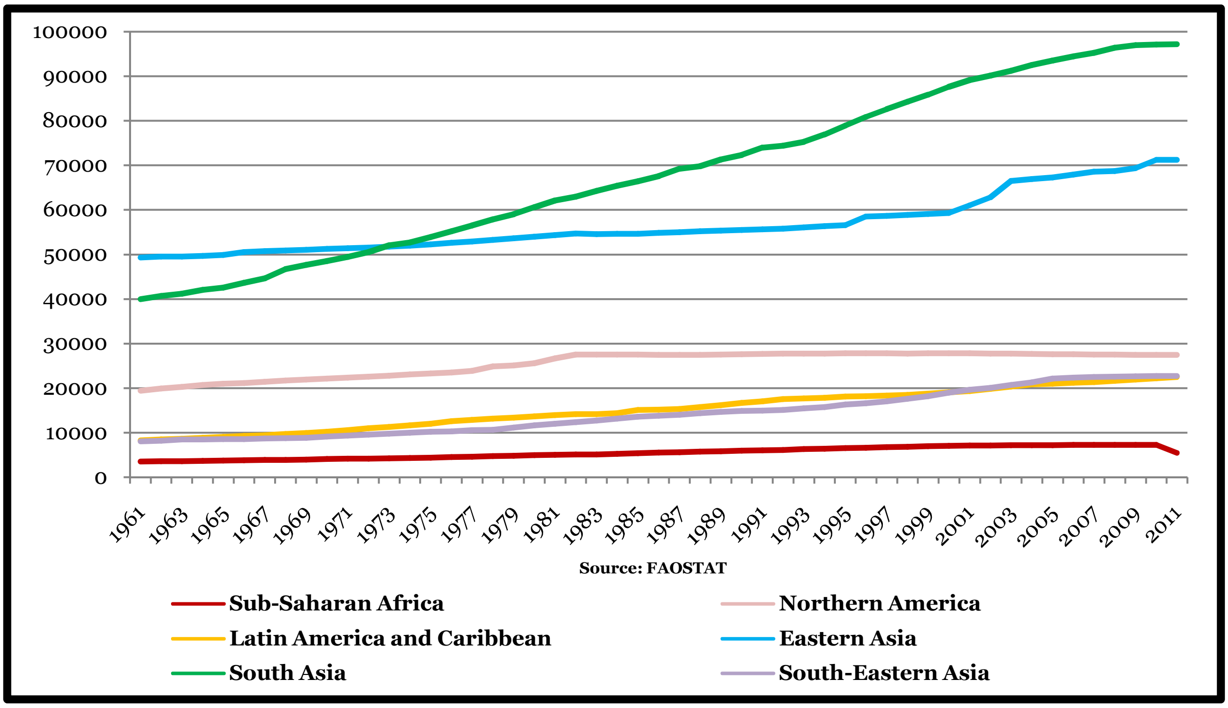
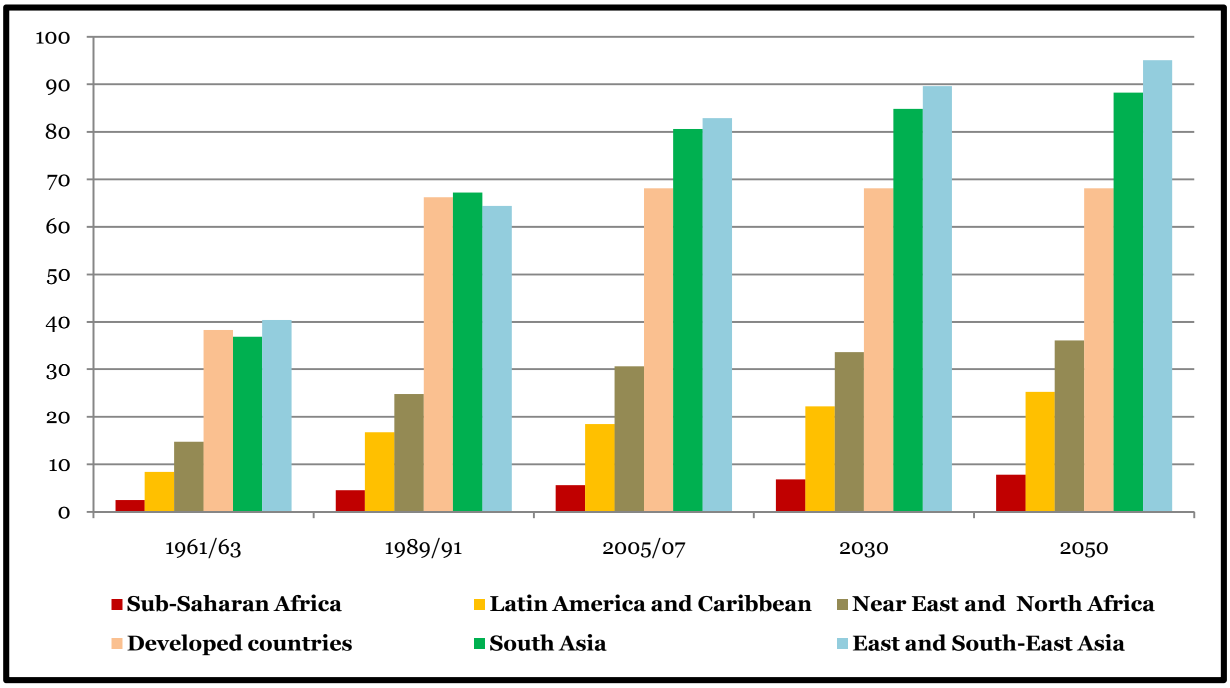
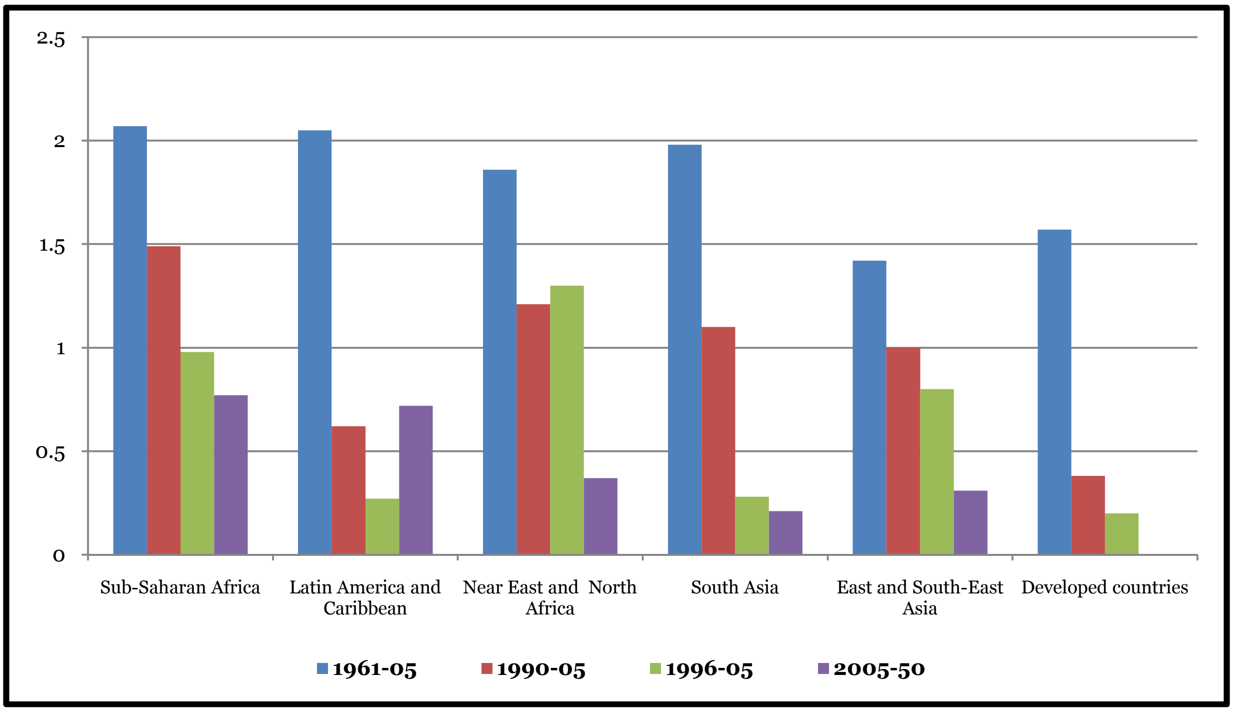


Figure 5b: Actual and Projected Total Area Equipped for Irrigation by Region (million ha) (1961-2050)



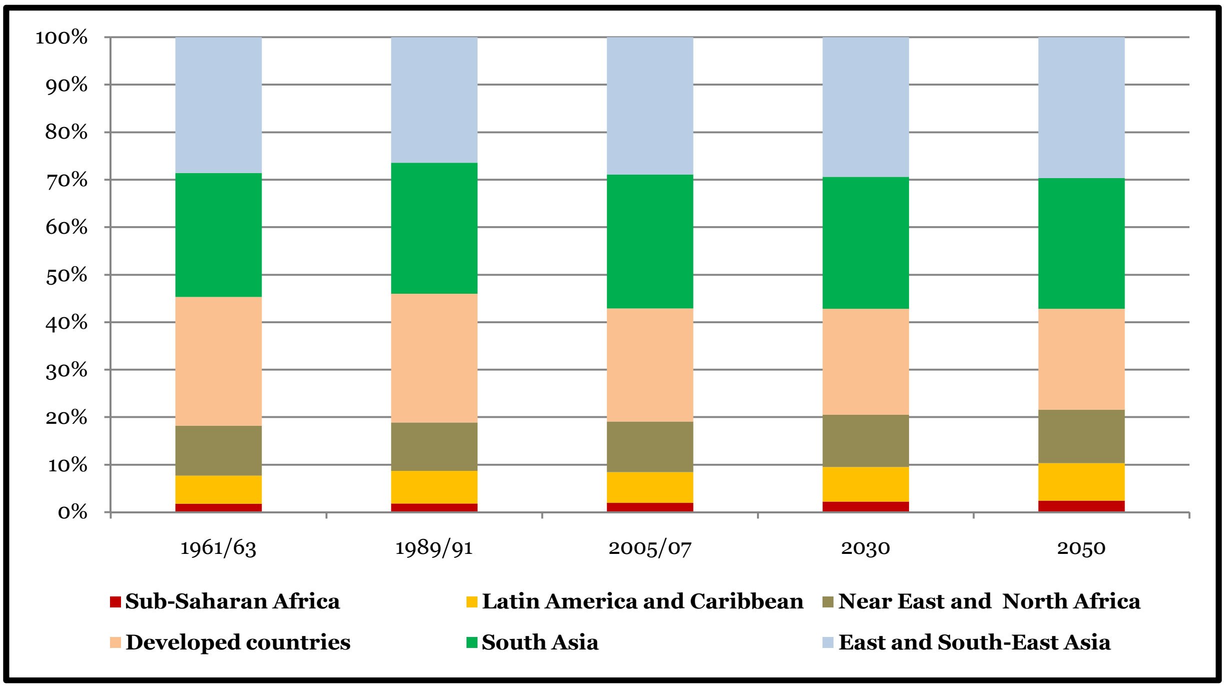
Source: Schmidhuber 2013.

Figure 5c: Actual and Projected Annual Growth Rates (percent per annum) of Area Equipped for Irrigation by Region (1961-2050)



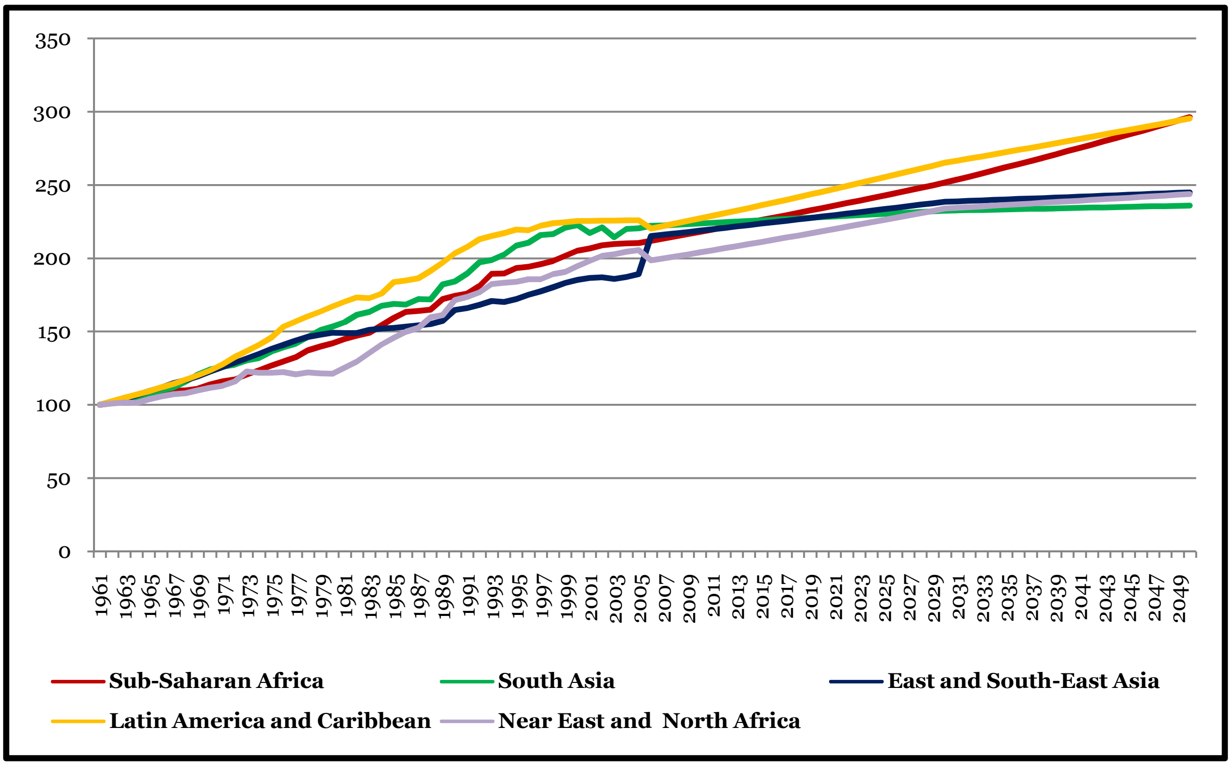
Source: Schmidhuber 2013.

Figure 5d: Actual and Projected Share of World Irrigated Areas by Regions (%) (1961-2050)



Source: Schmidhuber 2013.

Figure 5e: Actual and Projected Growths of Area Equipped for Irrigation by Region (1961-2050) (Base Year 1961=100)



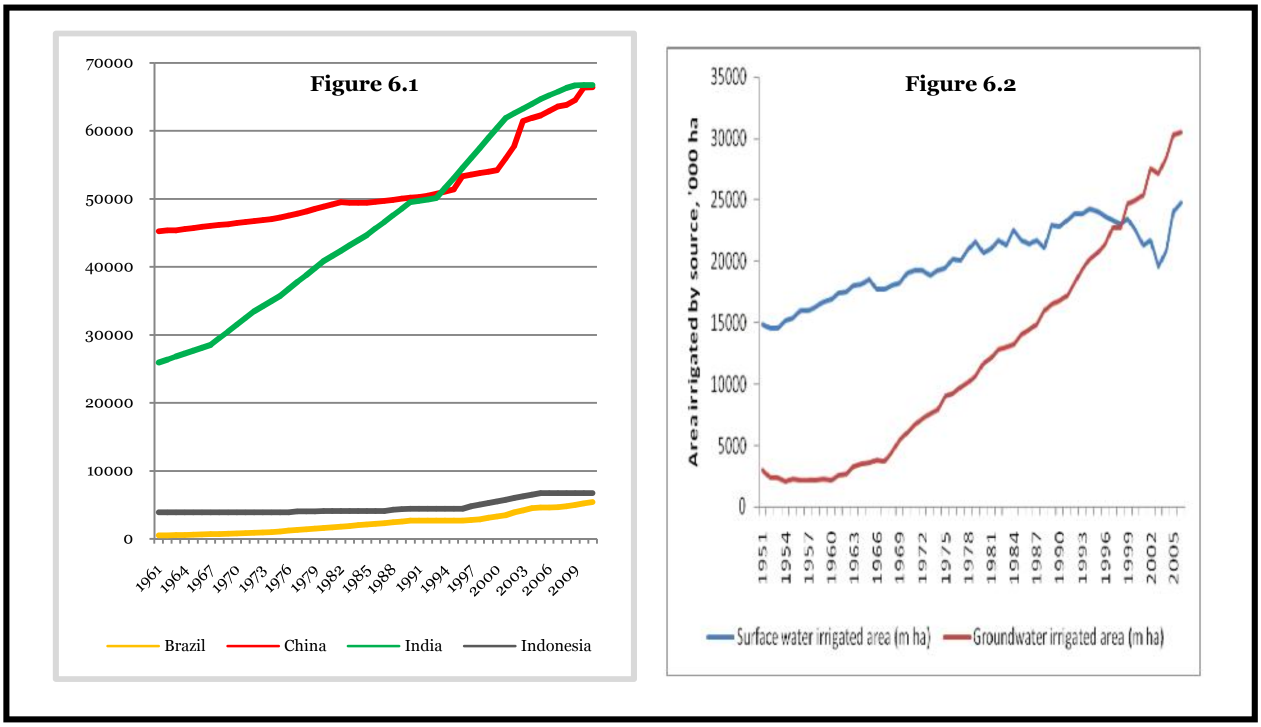
Source: Schmidhuber 2013.

Formal and Informal Irrigation and Relationship to Public and Private Financing

Sources of growth in irrigation have been quite different among regions. In South Asia, the growth has been largely through ground water exploitation funded largely by farm households in the form of tube wells as supplemental irrigation to the public sector formal irrigation systems. Growth in China on the other hand has been mainly through the expansion of the formal irrigation system. Water users' associations and distribution entrepreneurs are playing an increasingly important role in China in the operation and maintenance (O&M) of the formal, publically funded irrigation systems. Failure of canal systems to deliver adequate and timely water supplies is one major driver for the tube-well boom in command areas in South Asia, problems which Robert Chambers and Robert Wade before him chronicled (Chambers 2013; and Wade 1982). India has 65000 water users' associations compared to China's 50,000, but fewer in India are working well relative to those in China. Another is energy subsidies and untimely supply of power which leads to untimely supply of water, leading to irrigation by night well described by Chambers. The most important is the ability of tube wells to provide on-demand irrigation to farmers year round particularly to the tail enders who typically receive little or no water supply, a factor that should be at the centre stage of future improvement in public irrigation systems.

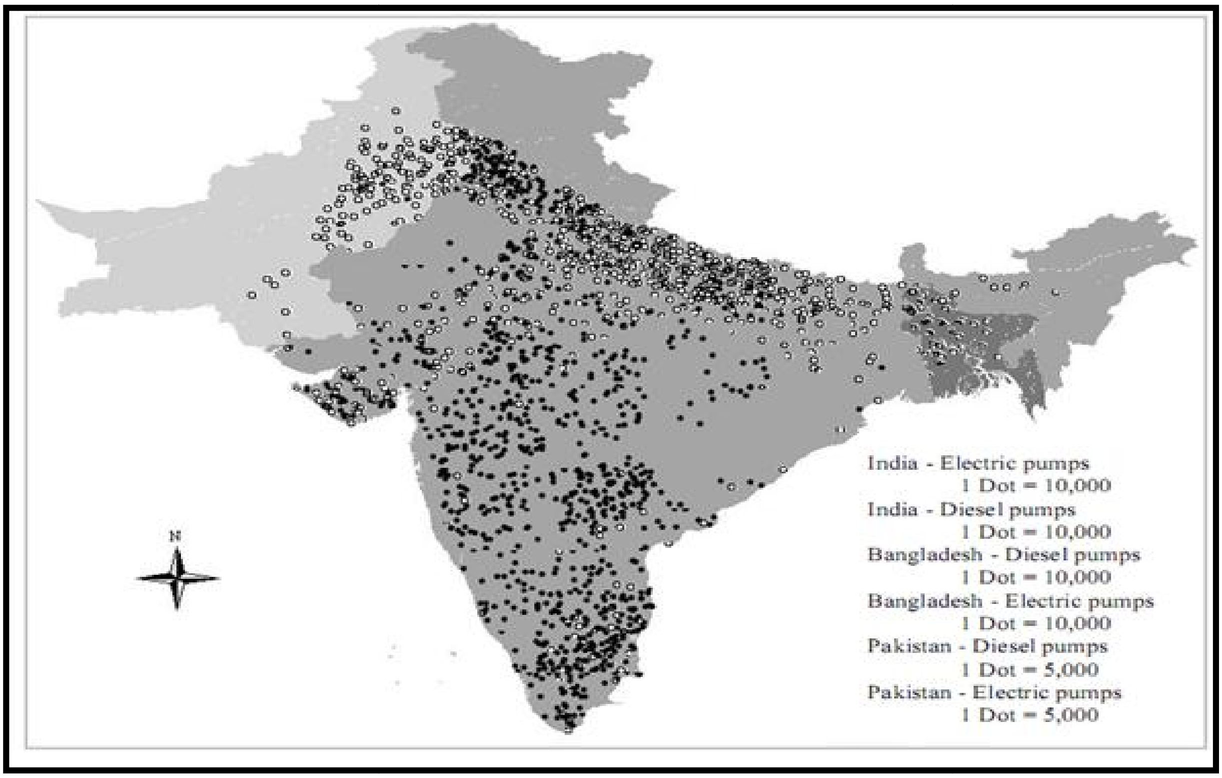
Shah et al and Chambers and Wade before them had noted, “India’s water sector is crying for institutional and policy reforms. Its public irrigation systems are performing far below par. As a direct consequence, farmers are turning to groundwater for their irrigation needs. Booming groundwater irrigation has become the mainstay of Indian farming but it has also all but wrecked the country’s power economy because of perverse policies of pricing of electricity for agriculture. Yet, there is no firm strategy of dealing with these and other challenges. Other South Asian countries are in much the same boat. Based on two spells of fieldwork in six provinces of north China, Shah et al show that, facing much the same problem as its South Asian neighbors, China is responding differently to its water problems” (Shah, Giordano and Wang 2004). China’s responses are described elsewhere and later in this paper (Lele 2013; and Lele et al 2013b). Of course wholesale transplant of approaches from China is neither possible nor the intention of this paper. Simple transplant of solutions would not work in India, and indeed even in all parts of China. However, China’s experience offers a wider repertoire of institutional alternatives with which to experiment, monitor, evaluate and learn lessons.

Figure 6.1 and 6.2: Total Area Equipped for Irrigation (Brazil, China, India and Indonesia) (1000 ha) (1961-2011) andGrowth of Surface and Ground Water in India (1951-2007)



Source: FAOSTAT for Figure 6.1 and Faures and Mukherji 2011 for Figure 6.2.

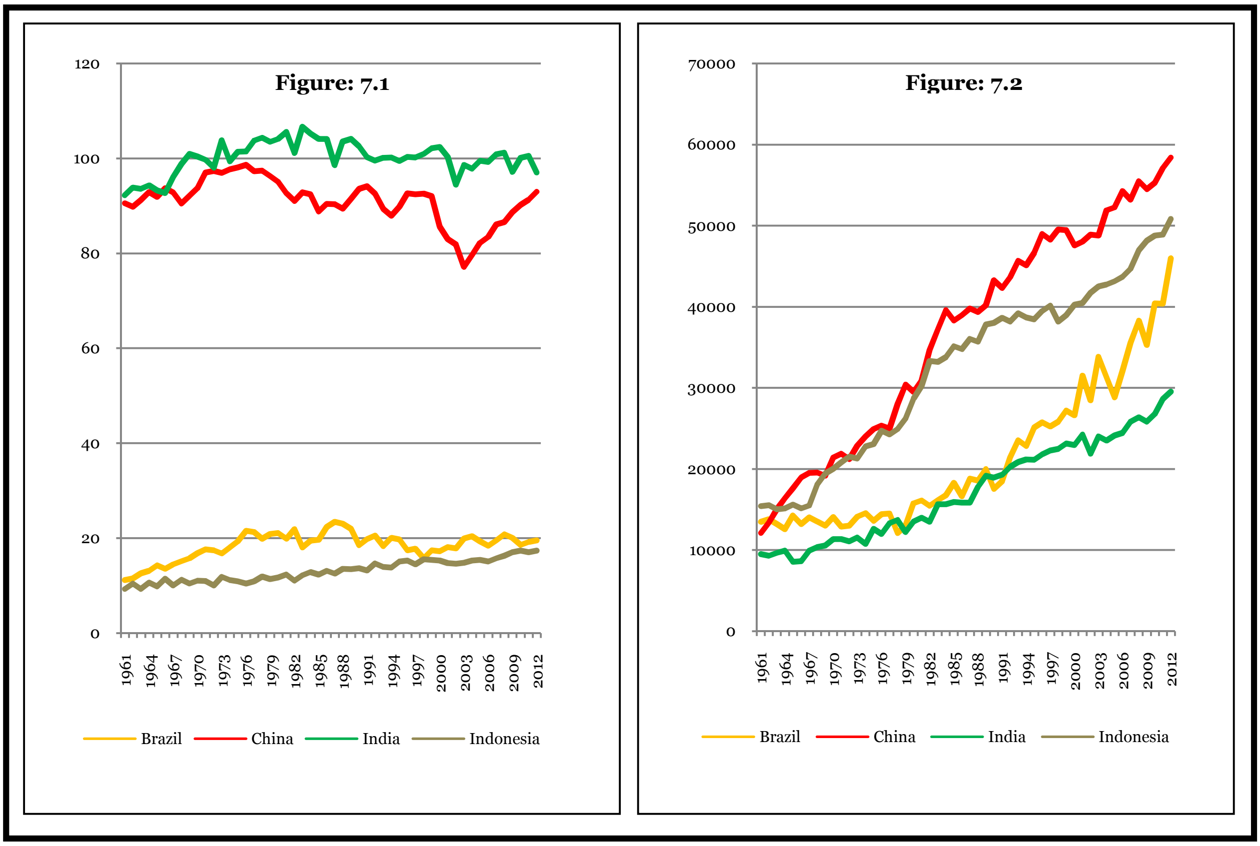
Map 1: Distribution of Electric and Diesel Pump-sets in South Asia



Source: Shah 2009.

Going forward issues of surface and ground water, already at the heart of the sustainability of water use in Asia, will also become important in Sub-Saharan Africa (Alexandratos and Bruinsma 2012). For India and China, by 2050 about 60 percent of all land with irrigation potential (about 417 million ha) will be in use, according to FAO, accounting for nearly 54 percent of irrigated area in the developing countries. Overall harvested area has already begun to decline in China and growth has slowed in India (Figure 7.1 and 7.2).

Figure 7.1 and 7.2: Total Area Harvested for Cereals (million ha) and Total Cereals Yield (hg/ha) (1961-2012) (Brazil, China, India and Indonesia)



Source: FAOSTAT.

“Although the overall arable area in China is expected to decrease further, the irrigated area would continue to expand through conversion of rain fed land” (Alexandratos and Bruinsma 2012). Similarly in the case of India nearly double the area with irrigation potential than currently irrigated exists according to FAO. In India growth in irrigation through groundwater exploitation and conjunctive uses of water from canal irrigation has been the greatest in dryer mostly western areas whereas the huge potential for groundwater and surface irrigation in eastern India remains untapped. Once again implications for irrigation financing are complex since some projects in South Asia entail interstate boundary issues, others trans boundary issues , still others private funding of the more flexible tube wells and still others, possibilities of small and large dams. These issues have begun to receive considerable attention in public discourse and in research and policy making circles in recent years in India. In short FAO’s numbers suggest more scope for conversion of rain fed land to irrigation in South Asia and China, with huge but unclear implications for sustainable resource use and nature of financing.

Brazil, increasingly a bread basket of the world has a completely different set of irrigation options. It reports 29.5 million hectares of land with irrigation potential compared to the 4.5 million under production currently (De Moraeis Cordeiro Netto 2013). While irrigation in the north and north-east and in the state of Parana is public sector, much of the rest to be developed could be farmer driven, surface irrigation. Whether it comes into production will depend on future global demand for food. And yet to realize the 2050 food projections of 60 percent, FAO argues productivity growth on existing lands would clearly be needed (both irrigated and rain fed) (Alexandratos and Bruinsma 2012).

FAO financing projections are the only and perhaps the best, global estimates. They must be interpreted with caution. They suggest an estimated investment of nearly $ 4 trillion needed in agricultural development by 2050, a quarter, or 960 million are projected to be in irrigation development and improvement. Nearly 80 percent of this investment is in depreciation. The rest 70 percent of the $4 trillion is the delivery of services (Table 3).

Table 3: 2009 FAO Projected Investment Needs From 2005-2050 in $ US Billion

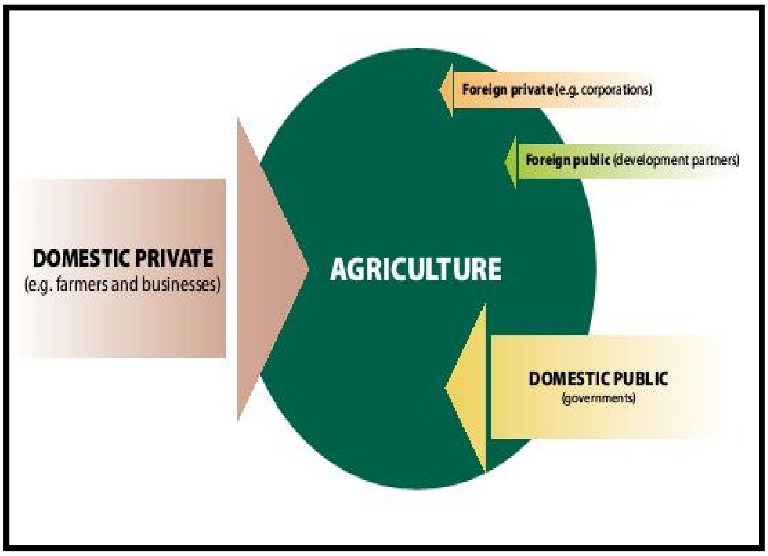
	Net	Depreciation	Gross
Total for 93 developing countries	3 636	5 538	9 174
Total investment in primary production	2 378	2 809	5 187
of which crop production	*864*	*2 641*	*3 505*
Land development, soil conservation and flood control	139	22	161
Expansion and improvement of irrigation	158	803	960
Permanent crops establishment	84	411	495
Mechanization	356	956	1 312
Other power sources and equipment	33	449	482
Working capital	94	0	94
of which livestock production	*1 514*	*168*	*1 683*
Total investment in downstream support services	1 257	2 729	3 986

Source: Schmidhuber et al 2009.

As Schmidhuber et al (2009) are careful to state; total investment requirements are made up of net additions to and replacement of obsolete capital stocks. Traditionally, the lion's share of capital needs has been covered by private farmers and by entrepreneurs in the related upstream and downstream industries (including capital outlays in non-monetized forms). Some capital items, such as irrigation development, rural infrastructure and agricultural research, require public intervention, but the authors make no effort to measure the needed or desired level of public sector engagement. This can vary widely across capital items and countries, and any quantitative assessment would need to start from a detailed and disaggregated basis.

These ideas above can be shown in a schematic from an FAO report (FAO 2012a) (Figure 8).

Figure 8: Sources of Investment in Agriculture



Source: FAO 2012a.

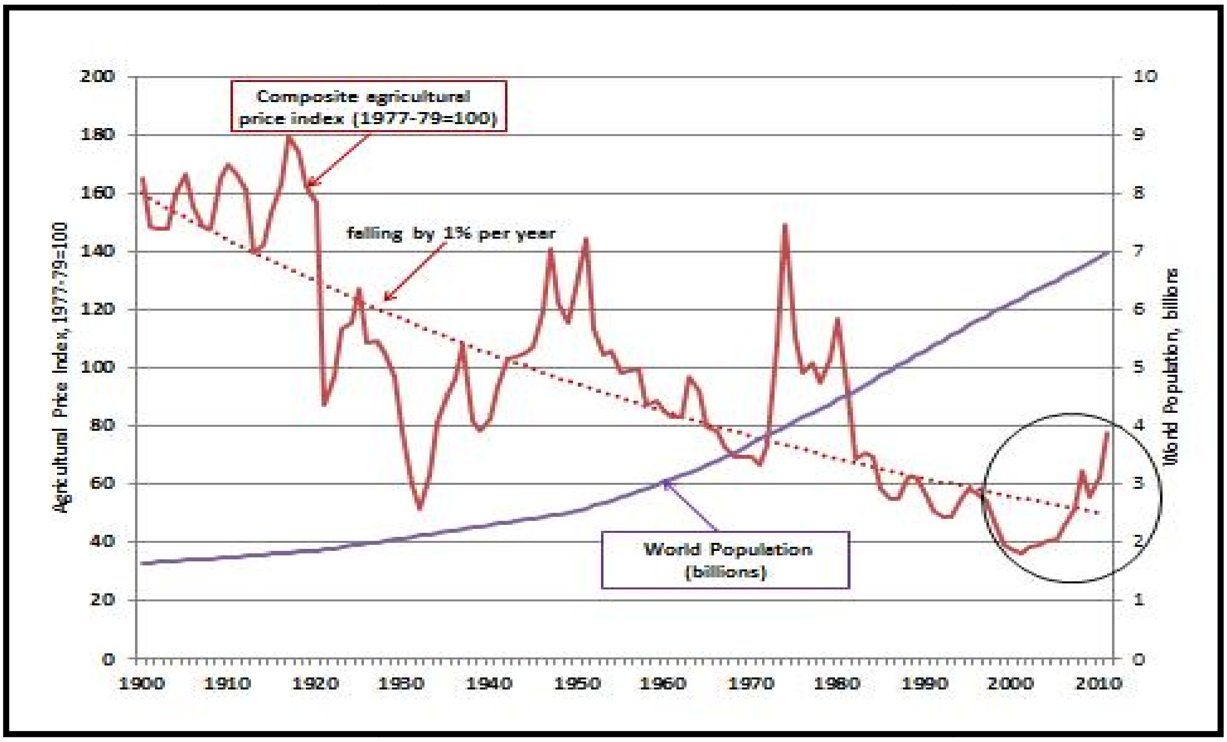
Sources of Investment in Irrigation and Drainage

Investments in Irrigation and Drainage have come from four different sources. Domestic and International Public and Private (including farmer investments) and together with complementary investments in other sectors they have made a difference to productivity growth. Clearly it is hard to predict what form this investment will or should take and what will cause it to materialize. Certainly future food and energy prices will influence incentives to invest, yet the form this irrigation will take in the future—whether large or small dams, surface irrigation, or tube wells, public or private investments will vary greatly among countries depending on the nature of their water resources, political, institutional systems and legal systems and technological options, and not the least the performance of their irrigation systems.

Role of Food and Energy Prices

There has been much discussion of the rising and volatile food prices and whether both the rise and volatility will continue. Economists are quick to point out that the recent prices are neither the highest nor the most volatile by historical standards despite the popularity of the rise and volatility narrative. As Figure 9 shows real food prices have been declining steadily for nearly 100 years because of increased investments in agriculture including in irrigation.

Figure 9: Real Agricultural Prices Have Fallen Since 1900, Even as World Population Growth Accelerated



Source: USDA, Economic Research Service using Fuglie et al 2012. Depicted in the chart is the Grilli-Yang agricultural price index adjusted for inflation by the U.S. Gross Domestic Product implicit price index. The Grilli-Yang price index is a composite of 18 crop and livestock prices, each weighted by its share of global agricultural trade (Pfaffenzeller et al 2007). World population estimates are from the United Nations.

At the global level how prices will behave in the future will in turn depend on investments in Research and Development (R&D) at the global and national levels. Rosegrant using IFPRI's Impact Models argues that increased investment in R and D can result in a considerable decline in prices (Rosegrant 2013). But his model reflects a complex interaction of factors in addition to investment in irrigation.[7] His model predicts three scenarios:

1. The business-as-usual scenario (BAU) projects the likely water and food outcomes for a future trajectory based on the recent past, whereby current trends for water investments, water prices, and management are broadly maintained.

[7] Crop area is a function of crop prices and irrigation investments, water input and climate change, yield is a function of crop rice, input price and irrigation investment, water inputs and exogenous yield growth, yield growth is a function of investment in agricultural research, irrigation and rural roads, food demand is a function of commodity prices, income and population, feed demand is function of livestock production, feed prices and feeding efficiency and biofuel demand is computed based on policy mandates and crush demand is a function of crush profit margins.

2. The water crisis scenario (CRI) projects deterioration of current trends and policies in the water sector.

3. The sustainable water use scenario (SUS) projects improvements in a wide range of water sector policies and trends.

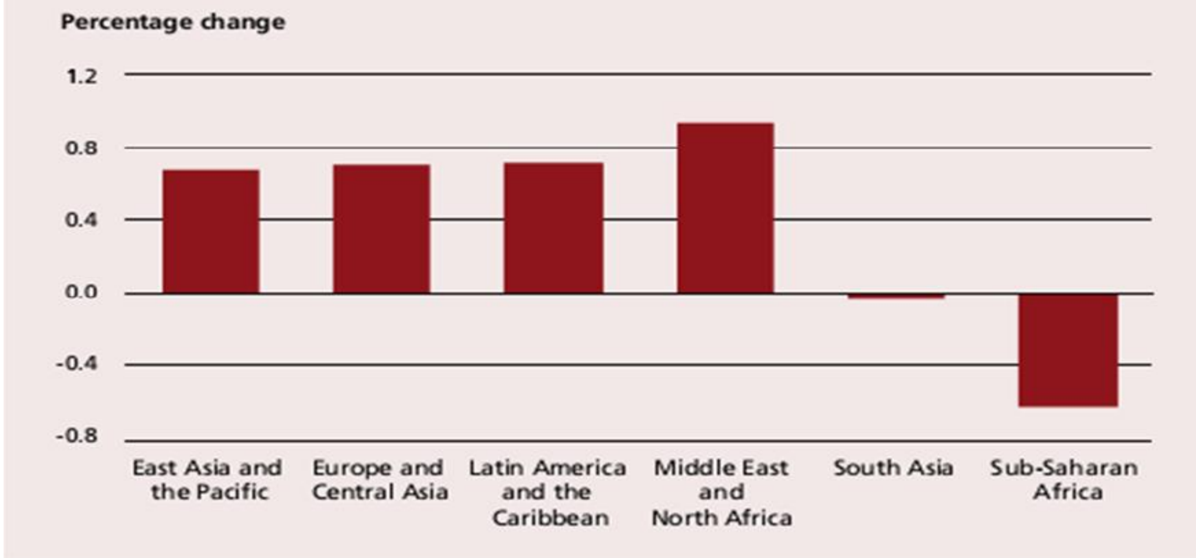
At the country level, however these scenarios will play out differently. Countries are not always highly integrated to international markets and prices due to the presence of trade restrictions, trade promotion, prices and subsidies, which distort domestic incentives to producers and affect water use by farmers. Using data for 109 countries over 30 years, evidence suggests that Asian food prices have been rising more rapidly since 2007 than prices in the rest of the world (Lele et al 2011) and most Asian countries including China, India and Indonesia have been subsidizing domestic producers to maintain a reasonable degree of domestic self-sufficiency, particularly since 2007. This has been affecting farmer decisions; e.g., more emphasis on water-using rice and less diversification.

Public Expenditures

National Expenditures'

National expenditures are by far the largest sources of investments in agriculture compared to international aid. Figure 10 below shows that the total capital stock per worker has been increasing substantially in regions that have experienced the most increase in productivity growth, e.g., in the Middle East and North Africa Region. The case of Morocco is discussed below. Furthermore while we typically think of investments in irrigation and drainage as coming from donors and private investors as discussed below, this FAO study rightly emphasizes that nearly 80 percent of all capital formation in agriculture comes from farmer. Furthermore the kind of an enabling environment the government provides makes a huge difference to the incentive for the private sector, including particularly farmers, to invest in agriculture. Farmer investments include substantial investments in water management as we show below. Putting farmers at the center of future irrigation investments and achieving results on water management on the ground in a sustainable way is the key and the focus of the rest of the discussion as phenomenon is shown in Figure 10.

Figure 10: Average Annual Change in Agricultural Capital Stock per Worker in Low- and Middle-income Countries (1980–2007)

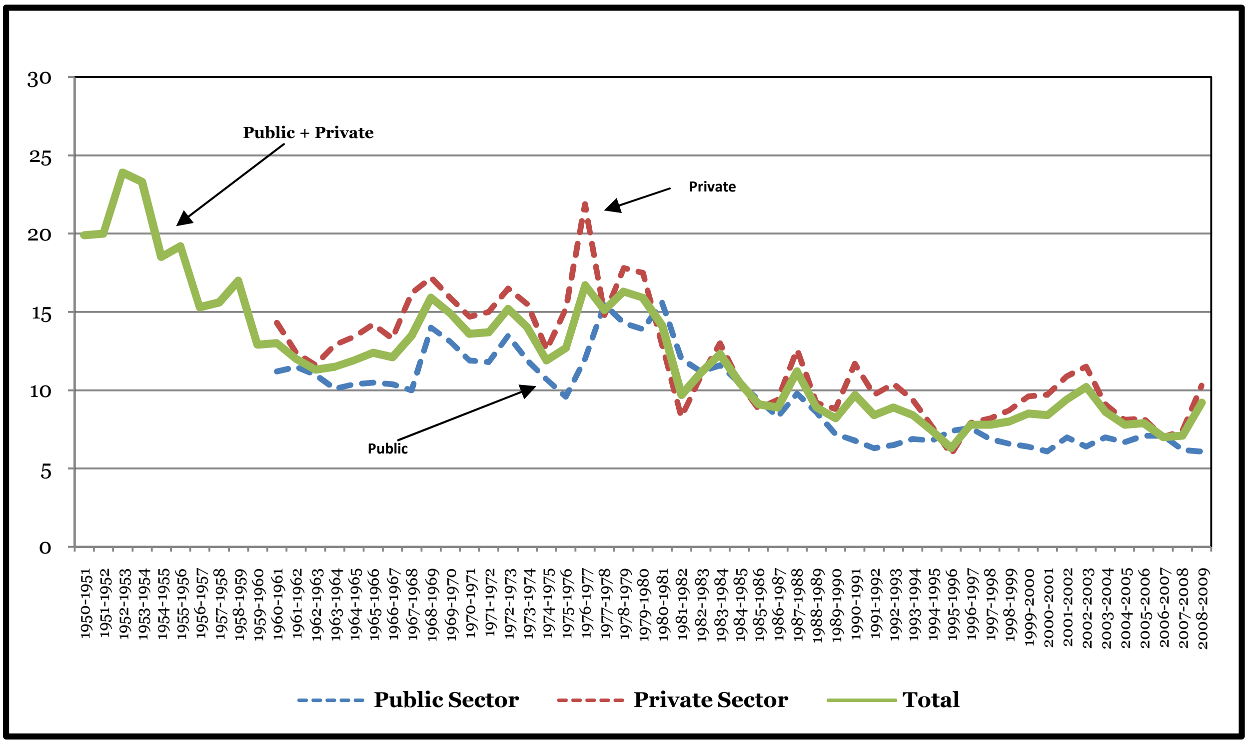


Notes: For countries in Europe and Central Asia, average annual changes are calculated for the period 1992 to 2007.

Source: FAO 2012a.

It is not surprising that the regions with the slowest productivity growth, namely, South Asia and Sub-Saharan Africa have shown little or no growth in average annual change in agricultural capital stock per worker. Public investments in agriculture in India amounted to 25 percent of planned expenditures at their peak, largely because of the importance of irrigation in investment but declined sharply over time and have just begun to recover in the 12th five year plan. Interestingly public and private investments in India are closely correlated.

Figure 11: Share of Agriculture & Allied Sector in Total Gross Capital Formation (Percent) in India (1950-51 to 2008-09)



Source: Central Statistical Organization (CSO), India.

The large differences in the level of public expenditures between China and India are striking. India's public expenditures on irrigation in the 12th plan are $70 billion over five years, i.e., amounting to between $12 to $15 billion compared to China's $60 billion annually, a huge difference given that they both have similar areas (about 66 million hectares each) under irrigation (Figure 6.1). China proposes to spend $600 billion over ten years in the water sector, in part to address issues of differed maintenance and in part to build huge new multi-purpose dams. The nature, not just of their irrigation investments, but the political economy of water management in the two countries has been very different as discussed in papers elsewhere (Shah et al 2012; Lele 2013; and Lele et al 2013b). An important consensus that seems to emerge from irrigation experts is the message to modernize, not just rehabilitate alone. Therefore, an important question going forward is how to establish an appropriate enabling policy and institutional environment including public–private partnerships for irrigation modernization going forward, given that private investments seem to be so closely, and not surprisingly, correlated with public investments. What is interesting furthermore is that the lions share both in China and India of "private investments" consists of farmer investments. Farmer investments have never before been systematically estimated, and indeed not even considered explicitly in the irrigation investments, as we do in this paper providing some estimates of farmer investments for these two giant countries. Furthermore, China's approach to water development may come closer to modernization of the irrigation system. But the idea of modernization also raises important issues of the transferability of the experience, for example from Morocco or China to the countries in South Asia. Not surprisingly the concept of modernization has not been without strong opponents. Since modernization goes well beyond infrastructure funding and encompasses major policy, institutional, and organizational reforms. The fact that land and water are state owned resources with state (central) authority vested in their development, allows China the freedom to act in a way that is far more difficult under India's constitution, where land, water and forestry are state (provincial) subjects and land is owned privately. Yet Indian states have shown capacity to reform albeit slowly, Gujarat being at the forefront, and now there is evidence to indicate that a few other states are following Gujarat's lead in certain areas and innovating on their own in other areas. We will return to the issues of modernization later in the paper.

Private Sector Financing

Private Financing has become a topic of much interest in recent years and much of it has focused on international finance discussed briefly below. Domestic private finance has not received much attention. Farmer financing is by far the largest share of finance and has received the least attention. Data on private financing are limited, fragmented and hard to interpret. For example, in South Asia, besides the nearly 15 million tube wells shown in investment in drip and sprinkler irrigation is expanding. Total micro irrigation area in India is 3 million ha; Gujarat alone has 700, 000 ha. Micro sprinklers are extensively used in groundnut, wheat and such field crops. Drips are widely used in cotton, castor, banana, sugarcane, etc.India is adding about 500,000 ha/year, over half of it in Gujarat alone. Shah estimates that Join, Netafim, Nagarjuna and other micro-irrigation companies have a combined annual turnover of around US 100 million. But that is small compared to overall public investment in government water works and in farmer finance.

By one measure public capital formation in major and medium systems between 1951 and 2010 is US $ 256 billion at the 2013 in purchasing parity terms (Vaidyanathan 2013). During the same period the estimate of private irrigation in India in wells, tube wells, pumps, pipes, drip and sprinkler irrigation systems carried out for this study turns out to be US $117 billion. At replacement cost, it amounts to $334.4 billion, perhaps equal to or larger than public investments (Unpublished paper by Mehta and Shah, prepared for this paper).

Public Private Partnerships

International Public Private Partnerships

In a separate paper for this conference Remi Trier of the World Bank discusses the recent international experience of public private partnerships in irrigation and drainage (Trier 2013). While public private partnerships (PPPs) are growing, albeit from a small base, they are still boutique operations in developing countries, according to Trier no more than 10 000 ha in 2013 (Guerdane in Morocco), 50 000 ha in 2015 (after completion of Olmos in Peru and 100 000 ha in 2020 with PPP in Brazil (personal communication). Thus they are not very significant in terms of the share of total global investments or the overall area under irrigation or agricultural production. From those reported by Trier it is hard to tell how many of those entail actual investments as distinct from management contracts, barring some, e.g. projects in Ethiopia. In any case, PPPs are being developed to accelerate irrigation expansion, improve operation and maintenance (O&M) services of public assets, and eliminate or reduce O&M subsidies from government, among other objectives. The Trier paper draws lessons from the experiences of early adopters, he calls "pioneer" countries, like Morocco, Peru and Ethiopia, West Delta in Egypt and the Pontal Project in Brazil, and transactions under preparation (Brazil, Morocco, Zambia and Ethiopia).He notes that the concession model is more appropriate for new and modern irrigation schemes with solid water demand from commercial farmers, while management contracts seem more appropriate for smallholders. Trier has a good treatment of good and bad practices for transaction design to reduce risk, and rightly stresses that PPPs should be seen as an additional tool and not a new "panacea." In any case, they could become one of the means of modernizing the existing irrigation systems, provided the benefits of modernization can be assured and monetized. Since they are a new tool, they should be carefully monitored to learn as many lessons as possible of the kind Trier includes in his paper.

Towards Modernization: Experience of Developing Countries

Among developing countries in North Africa, **Morocco** has had a relatively advanced irrigation system since the 1960s with a high level of agricultural productivity for some crops, particularly industrial and export crops. With increasing food prices Morocco has been under pressure to become more self sufficient in food, including wheat and cereals, **Morocco** has now embarked on an important investment programme to further increase the total factor productivity in the irrigation sector, aiming not only at producing higher yields per unit of water but also at generating more dollar value and more importantly more jobs.

The Moroccan programme comprises 3 components: The first component consists of an integrated modernization of irrigation schemes. This involves replacing open canals with pressurized systems, or improving existing pressurized systems to ensure that service is more reliable, demand based, individual farmers can be served separately (rather than as a block as in the current rotation based system). It also involves rehabilitating and improving regulation of canals with a view to improving service and reducing losses from those canals. This will allow the irrigation agencies (ORMVAs) to determine a safe quantity of water which they can guarantee to enter into a contract with farmers for that amount.

The second component helps farmers make the best use of their guaranteed quantity of surface water. It aims to enhance their knowledge, access to technology (mainly drip irrigation), their access to financing and markets by promoting partnerships with agro industries, supermarkets, banks and providers, and forming water users' associations.

The third component supports: (i) applying systems to monitor water losses in the canals and water consumption in each scheme; (ii) information to farmers about weather conditions and recommended irrigation quantities and timing, mobile laboratories and capacity enhancement; (iii) public awareness campaigns.

Morocco's aim is to increase the irrigation agencies' financial viability through adequate tariffs and cost recovery policies and make PPPs for irrigation development and management more attractive. A pilot project for conversion to drip irrigation is being implemented with World Bank financing, in the Oum R'Bia basin.

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In order for the second and the third components to be implemented, the first one has to have reached its objectives. This modernization program with conversion from gravity to pressurized systems and adoption of drip is a model for water scarce countries in MENA region.

Under World Bank financing **Vietnam** introduced a program of modernization in 2004.

Another example is the case of the Rio Elqui in **Chile** where the disputes over the water diverted by each traditional canal along a river in the north have been solved by the installation of precise automatic and precise water control equipment (high-tech gates).

Volumetric pricing, delivery of the needed water on time and farmers' willingness and ability to pay are important characteristics of these systems.

A typical manually gated irrigation district in Peru where volumetric delivery and water charges are combined with high quality irrigation service based on individual farmer demand is an interesting example of a project where institutional reforms, in particular a strong farmer water user association, have been successfully adopted and helped compensate for deficiencies in irrigation system infrastructure. However this model was not replicated in Peru because the unique conditions are not found elsewhere, especially the mutual social control and participation of the users and the dedication and skills of the operators.

Irrigation systems in **East and South East Asia and South Asia** have a long way to go for the type of modernization discussed above. In South Asia, the first objective is to reduce the chaos in water delivery and to improve the reliability and flexibility of service to farmers, what Tushaar Shah has aptly termed "Taming the Anarchy".

A 64 million (or billion?) dollar question is: How can modernization be fitted into the vast and complex existing public irrigation systems of the **Asian Giants**? **China and India** started decades ago with similar conditions of poverty and resource endowments, but the political systems, governance, institutions and policies have evolved very differently. China's water management system represents a relatively "formal" command and control bureaucratic system, similar to the system India inherited from the colonial period, e.g., in the Indo-Gangetic plain, while India has evolved politically into a decentralized democracy but has preserved almost intact the bureaucratic irrigation administration and management system from its colonial past. Critics argue that the colonial system (including its hardware and software) was never intended for high productivity agriculture and it is outmoded. In addition, there is a fundamental difference between the two countries in terms of their Constitutions and Property Rights. In China, land and water are State (government) assets while in a Federal India; land and water are state (provincial) subjects, meaning the responsibility of the states to manage. Water, in public bodies, has increasingly defacto become a common pool good and on private lands a private good. Water conflicts have increased in India at all levels, ranging from the local to transboundary. They are compounded by unsustainable groundwater exploitation, the fact that its agricultural strategy has centered on rice and wheat and is less diversified than it could be under a proper pricing regime and relative for example to China, and by its dependence on large power, water and other subsidies (Shah and Lele 2011; and Shah et al 2009). These factors lead to questions about the sustainability of India's current model for irrigation development.

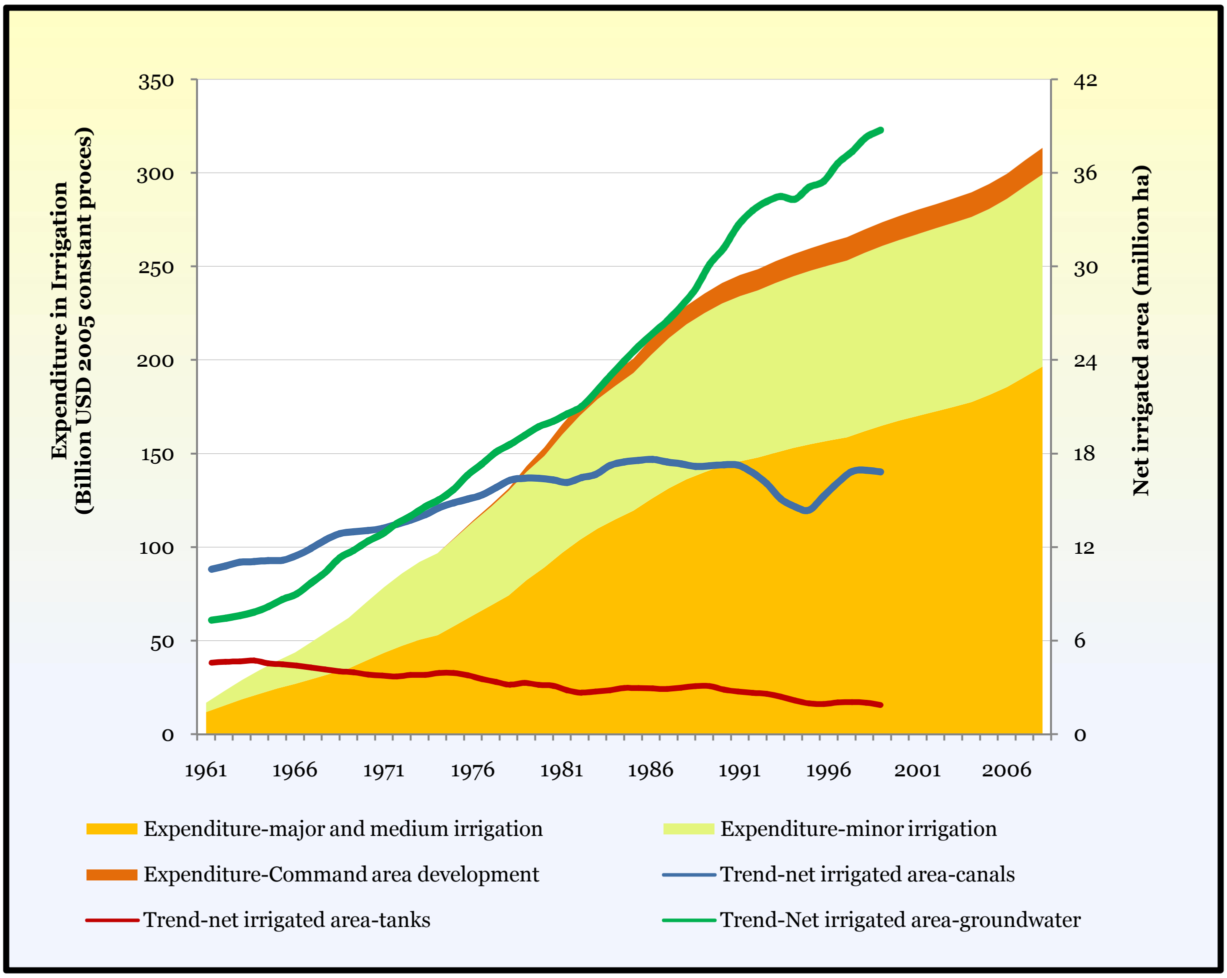
China has invested heavily in canal lining and focused on specific aspects of modernization, like pipelines and farmer Water User Organizations (WUAs). The medium- and long-term effects of this, particularly on groundwater recharge and biodiversity protection in some areas of China, are questioned by some, e.g., (Shah et al 2004). However, it has sought to assure adequate water supplies to farmers relying on canal irrigation. Most observers note that China's average canal irrigation efficiency at 50 percent[8] is comparable to that of most other well run irrigation systems (up to 75 percent is possible in the best systems). There is extensive investment in pumped irrigation, and use of farm budgets and water allocation measures. But Chinese analysts question if this allocation system is based on real farmer needs and demand (Lele's interviews in the Nanjing Area). Volumetric pricing for irrigation services to farmers is the bedrock of efficient irrigation system management, but in China so far it is practiced mainly where farmer-managed WUAs operate, which is currently estimated to cover about 35 percent of the total irrigated area; the most advanced WUAs buy water from the main irrigation system operators

[8] This is the ratio of the amount of water needed by a crop to the amount turned into a canal at the head works. This value does not account for any possible reuse of seepage water by others downstream.

(Irrigation District Management Bureaus) by volume based on farmer demands, distribute the water to their members and collect the water charge needed to pay for the water. Irrigation service fees vary considerably from US$70/ha (CNY 450/ha) for canal irrigation to US$450/ha (CNY 3,000/ha) for pumped irrigation. The latter is used mainly for high value crops, such as vegetables and fruit. Significantly, high service fees have driven farmers to economize on water use and also to switch to higher value crops in some areas. Several studies are under way to assess the impact of the new policies on water use and productivity, some of which are discussed below. There are still many critical issues to resolve on water allocation and pricing mechanisms in agriculture, but the dual approach of WUAs and responsive irrigation district managers seems to be working. This strategy is also supported by the increased voice of stakeholders in the local irrigation policy-making process. Moreover, and perhaps most important, China has demonstrated enormous capacity to learn from its own successes and failures and from those of others.

Shah et al (2012) have argued that even if a country like **India** were to replicate the Chinese style modernization, it is doubtful if results would be similar without a strong authority system at all levels represented by the Communist Party of China, a uniquely Chinese feature; clearly Party support at all levels is essential to smooth working and spread of WUAs. Even so, the contrast between where canal irrigation is headed in India with that in China is striking. Shah notes irrigation bureaucracy is shrinking in India but growing in China. Planning and investment are focused on construction in India but on modernization in China. State governments are focused on minimizing irrigation budgets in India; in contrast, provincial and local agencies are focused more on improving service delivery and system performance in China but as cost-effectively as possible. Farmers in India pay low or no Irrigation Service Fees (ISFs) and receive poor or no irrigation service; farmers in China pay relatively high ISFs and receive a relatively better level of irrigation service, especially where WUAs are in operation. After 30 years of pushing WUAs, Participatory Irrigation Management (PIM) in India has made little progress. China began WUAs based on PIM in 1995 under a series of World Bank and domestically financed projects, but after about 2004 China has spread them rapidly and widely; it has tens of thousands of strong WUAs that have taken over irrigation management responsibilities at the tertiary level. Due to a substantial irrigation management vacuum at the irrigation systems level, Indian irrigation systems are increasingly becoming groundwater recharge systems, with farmers recycling the seepage water from unlined canals and inefficient field application using tens of thousands of tube wells. In contrast, thanks to growing service orientation through intensive management needed to serve WUAs on demand, Chinese Irrigation District managers and staff in systems with farmer-managed WUAs are able to provide near tube well-quality irrigation service from canals. In India, with their insignificant revenue generation due to poor service and virtual total lack farmer participation (as with WUAs), funds-strapped irrigation systems is hurtling towards a build-neglect-rebuilt syndrome, a vicious downward cycle. In contrast, by providing high level irrigation service for which WUA farmers are more willing to pay, Chinese irrigation systems with WUAs are able to generate sufficient revenues to be able to invest in good O&M and improve management capacity, resulting in a virtuous upward cycle. If India wanted to take to the path of irrigation management reform, perhaps the first step would be to start working on the last contrast: shift from low ISF and low level of service to a rational ISF and improved, reliable irrigation service based on farmer demand in terms of timing, quantity (limited) and flexibility. China has made a decision and commitment to improve irrigation service, at this point using WUAs and direct farmer participation to improve irrigation management and service to farmers. India has yet to make such a decision.

Figure 12: Public Expenditure in Irrigation and Net Irrigated Area in India



Source: Unpublished paper by Mehta and Shah.

In Africa, The Comprehensive Africa Agriculture Development Programme (CADAAP) has had a target of 10 percent of total government expenditures which has not been met by most governments.

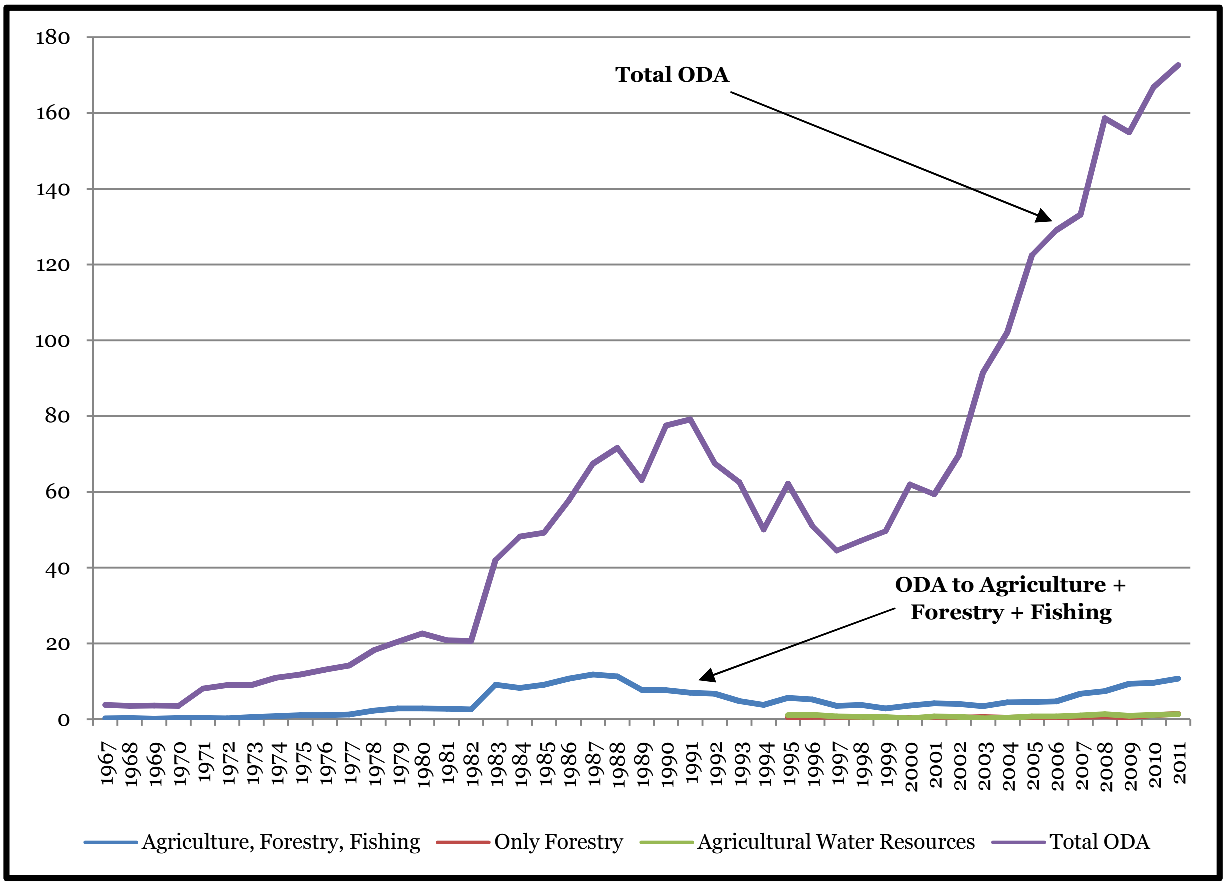
International Aid to the Irrigation and Drainage Sector

Data on OECD countries' aid to the agricultural water resources sector (which includes irrigation, reservoirs, hydraulic structures, ground water exploitation) is available only from 1995. World Bank commitment and disbursement data on the other hand are available since the 1950s. Overall ODA increased sharply from 1967 to 1979, plateaued until 1981 at about $21 billion in nominal terms in 1982and then rose very sharply again to nearly $80 billion until 1991 before dropping until 1997 to about $44 billion and then rising again sharply and reaching well over $170 billion until 2011, the latest year for which data were available at the time of writing of this paper.

Aid to agriculture was the highest in nominal dollars between 1983 and 1987 after which it declined until 1999 and rising slowly thereafter since 2005. ODA to irrigation was about $1 billion in 1995 but then declined sharply to only $254 million in the year 2000 rising to $1.3 billion at the peak in 2008 (Figure 13).

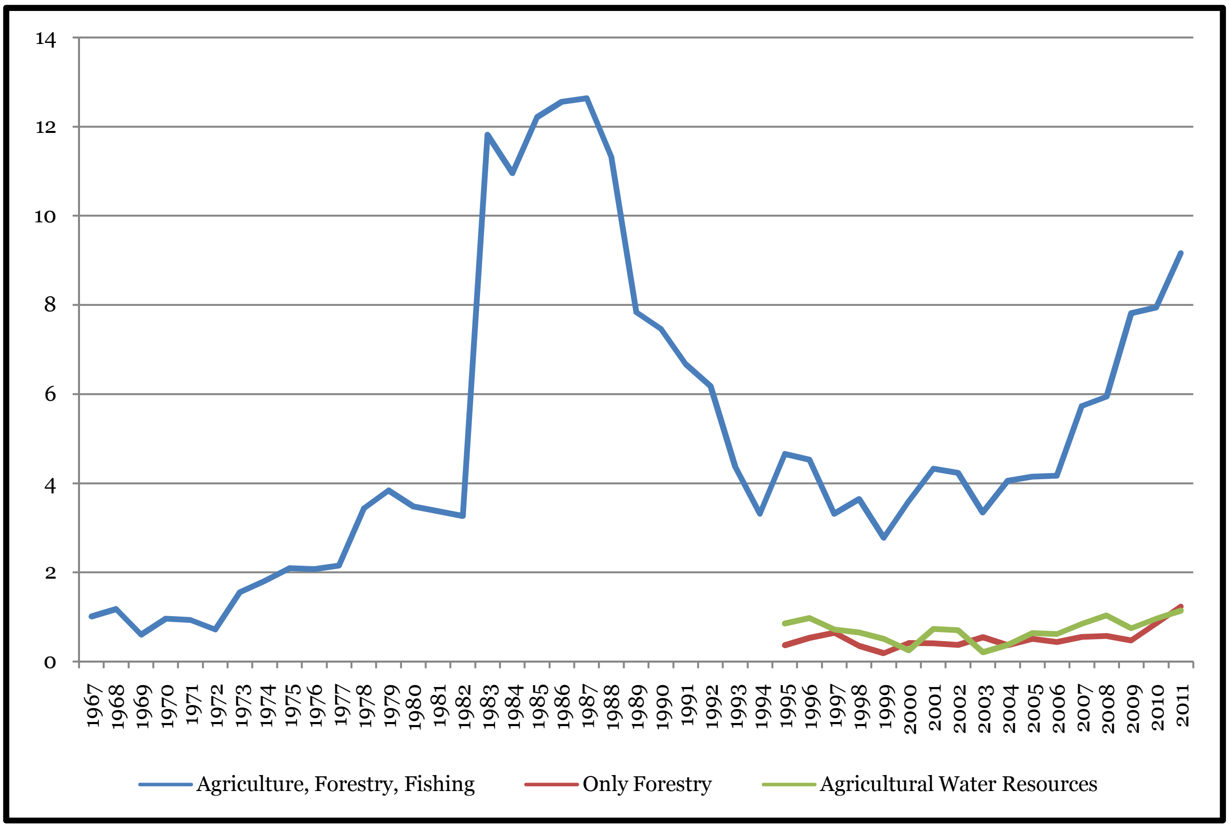
As share of total aid, aid to agriculture reached a peak in 1983 at 22 percent of the total, the highest share ever, but then declining to as low as 4 percent share in 2006, before rising again to 6.2 percent by 2011.

Figure 13: Total ODA and ODA to Agriculture + Forestry + Fishing, Forestry (Only) and Agricultural Water Resources* [Current Prices (USD billions) (1967-2011)]



* The data on Agricultural Water Resources (i.e., Irrigation, reservoirs, hydraulic structures, ground water exploitation for agricultural use) and Forestry (only) are available since 1995. Source: http://stats.oecd.org/Index.aspx?DatasetCode=TABLE5.

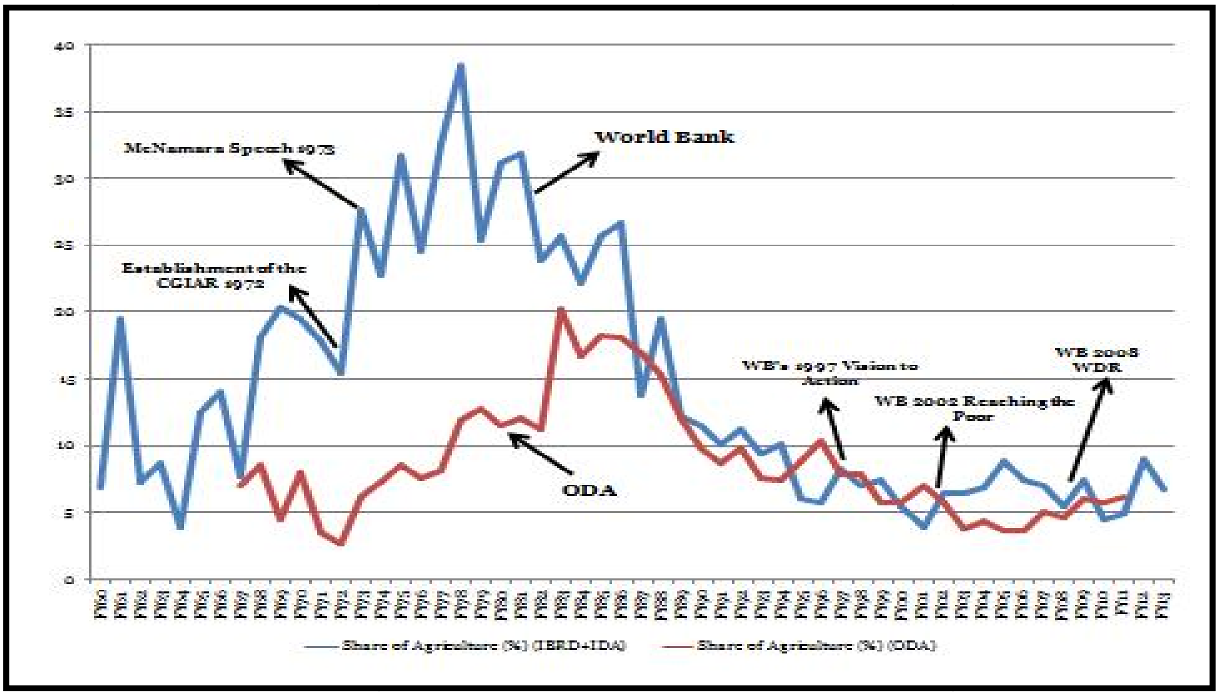
Figure 14: ODA to Agriculture + Forestry + Fishing, Forestry (Only) and Agricultural Water Resources* (US$ Billion) (Real=Nominal/MUV) (MUV Index 2000=100) (1967-2011)



* The data on Agricultural Water Resources (i.e., Irrigation, reservoirs, hydraulic structures, ground water exploitation for agricultural use) and Forestry (only) are available since 1995. Source: http://stats.oecd.org/Index.aspx?DatasetCode=TABLE5.

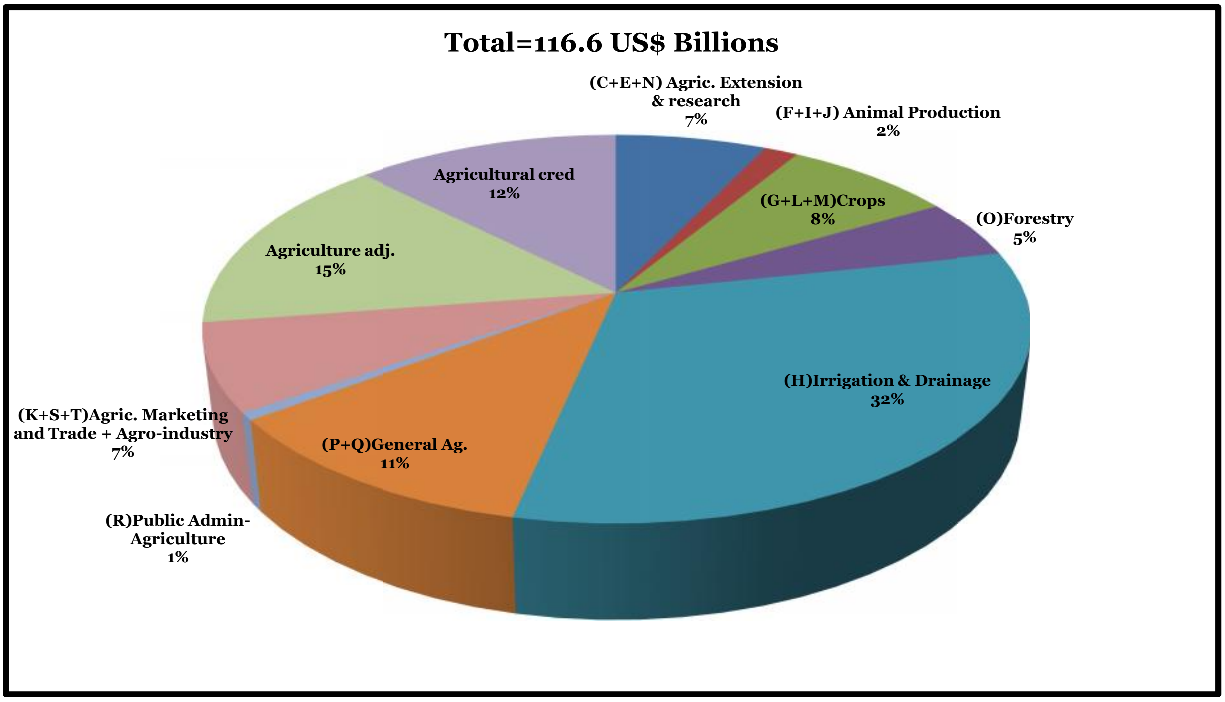
The share of agricultural lending in total World Bank lending was at its peak in 1977. The share of-irrigation and drainage lending in total agricultural lending was quite high in the World Bank lending, an average of about 32 percent of the overall World Bank agricultural lending between 1960 to 2011, but had declined from the peak in the 1970s.

Figure 15: Share of World Bank and Overall ODA going to Agriculture, 1960-2013



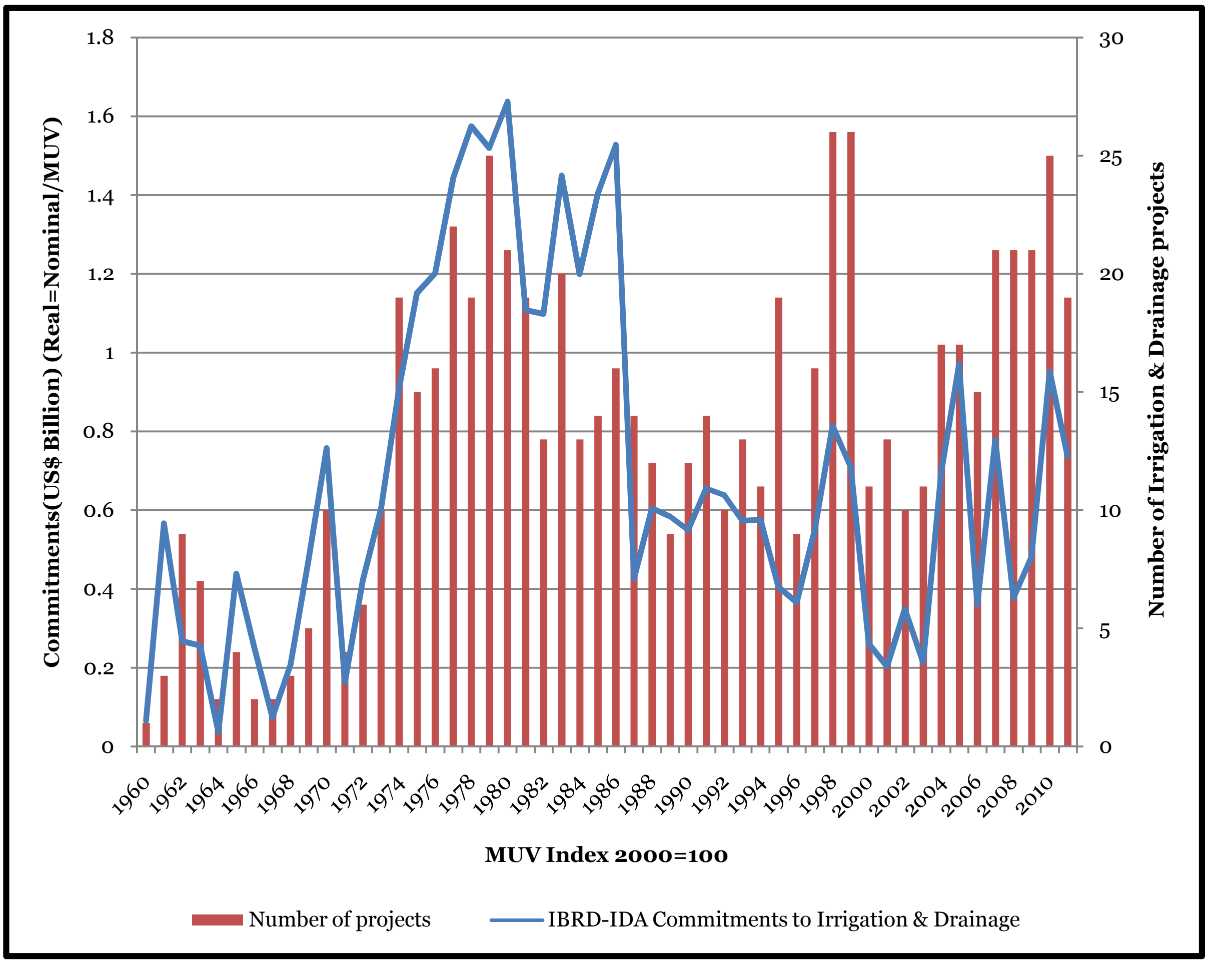
Source: http://stats.oecd.org/Index.aspx?DataSetCode=CRSNEW# and World Bank Projects and Operations. http://www.worldbank.org/projects/.

Figure 16: Share of IBRD-IDA Total Commitments by Agricultural Sub-sectors (Real=Nominal/MUV) (MUV Index 2000=100) (1960-2011) (%)



Source: World Bank Projects and Operations. http://www.worldbank.org/projects/.

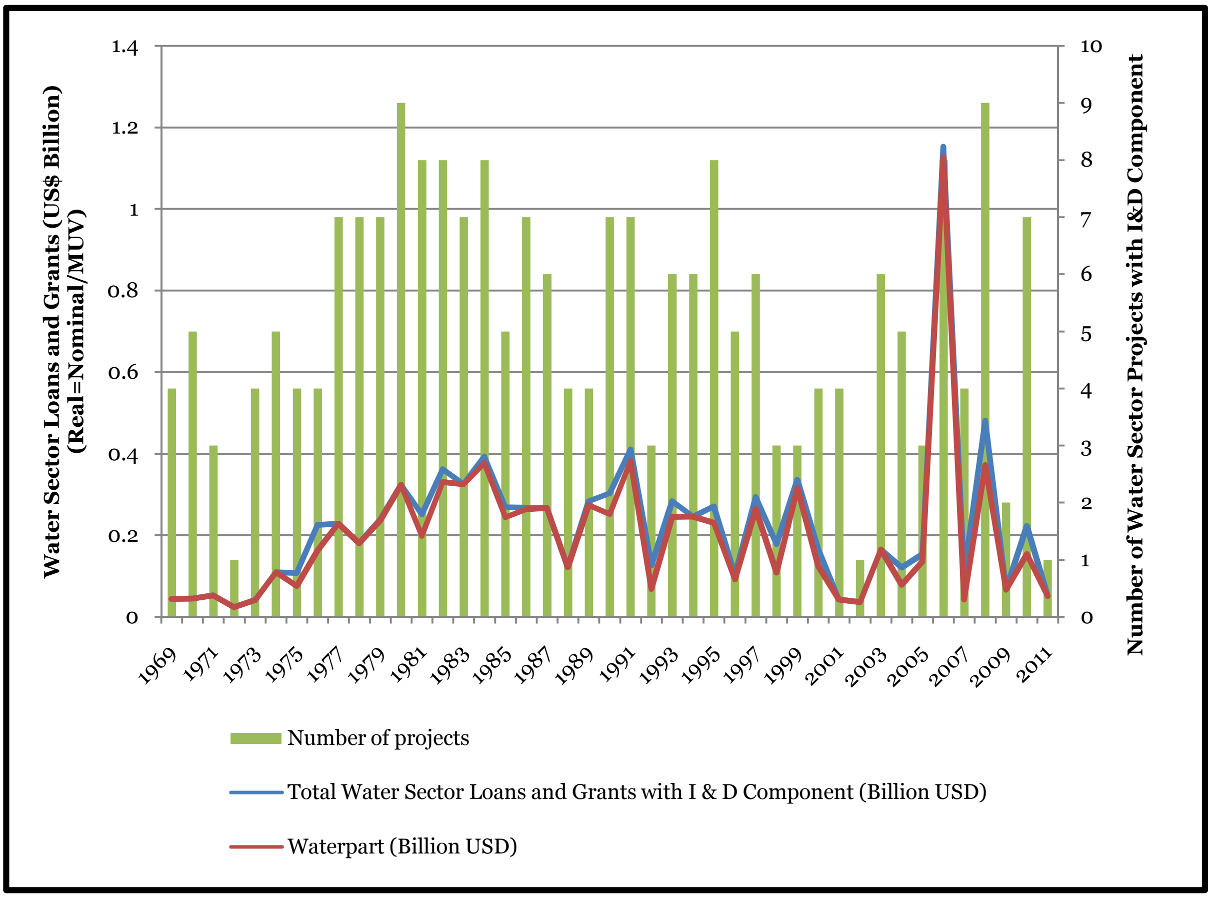
Figure 17: Number of Irrigation & Drainage Projects Funded by IBRD-IDA and Total Commitments to Irrigation & Drainage (US$ Billion) (Real=Nominal/MUV) (1960-2011)



Source: World Bank Projects and Operations. http://www.worldbank.org/projects/.

The lending by the Asian Development Bank has been smaller than the World Bank's and has also been declining barring one significant peak in 2007 of a loan to Pakistan.

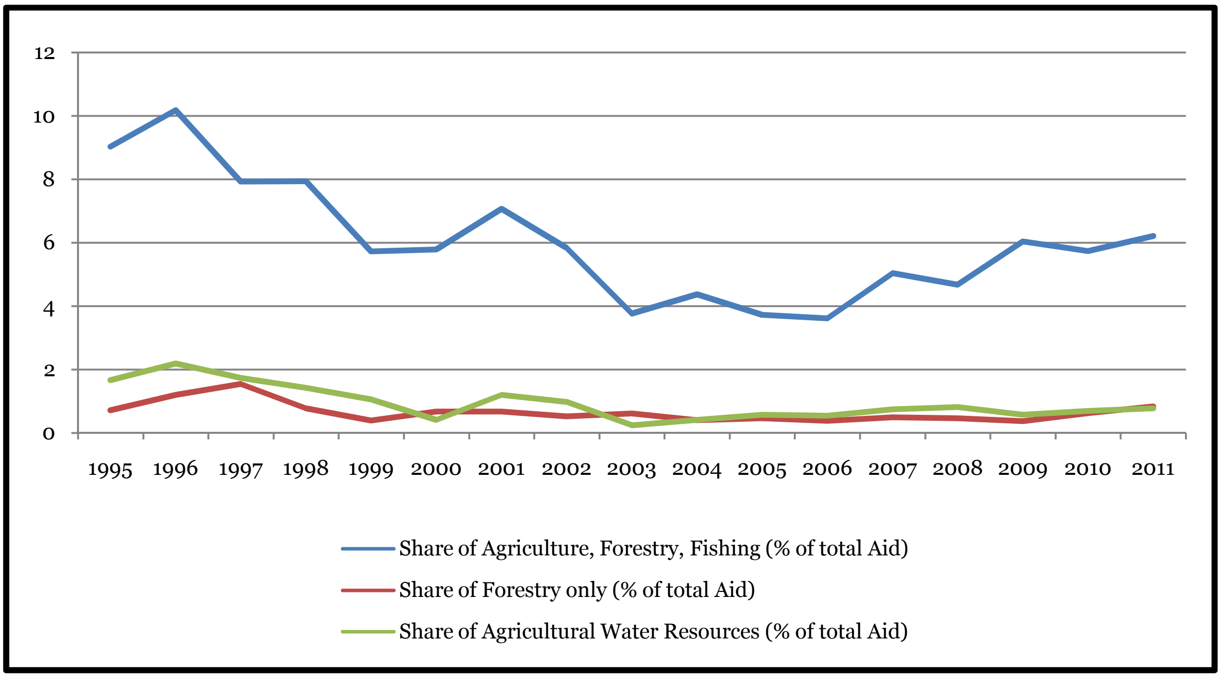
Figure 18: Number of Water Sector Projects with I&D Component Funded by ADB and Total Water Sector Loans and Grants with I&D Sector (US$ Billion) (Real=Nominal/MUV) (1969-2011)



Source: Asian Development Bank. Statistics and Databases.

The share of irrigation and drainage in overall ODA has declined from 2percent to 0.4 or 0.2 percent.

Figure 19: Share of Agriculture + Forestry + Fishing, Forestry (Only) and Agricultural Water Resources* in Total ODA (1995-2011)

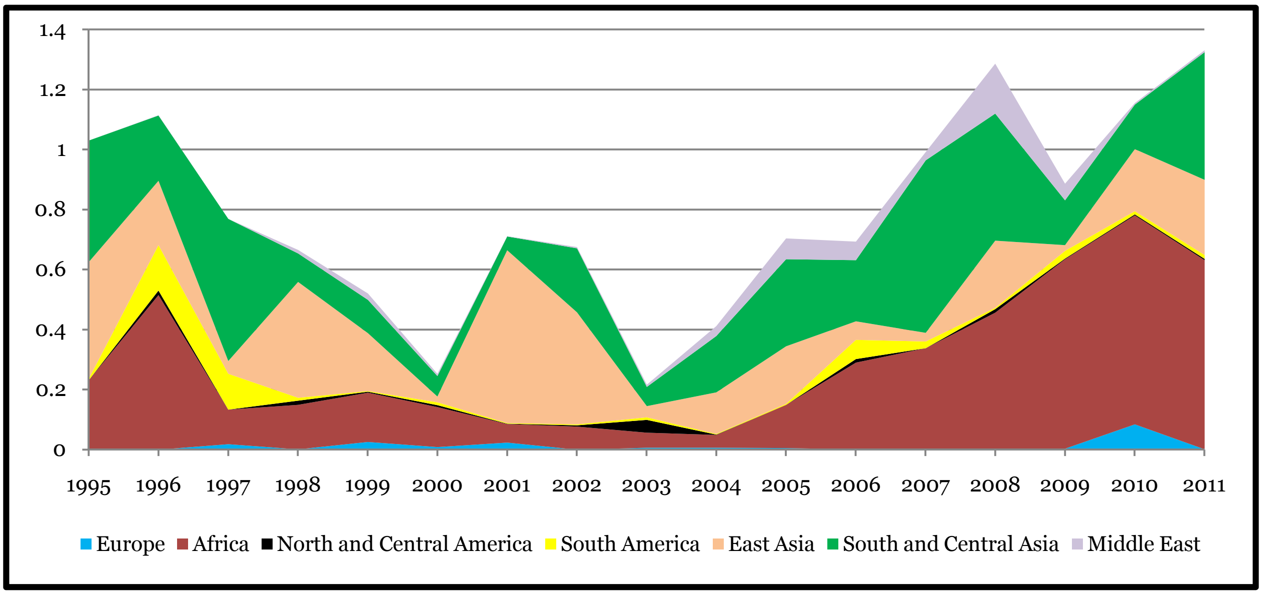


* The data on Agricultural Water Resources (i.e., Irrigation, reservoirs, hydraulic structures, ground water exploitation for agricultural use) and Forestry (only) are available since 1995. Source: http://stats.oecd.org/Index.aspx?DatasetCode=TABLE5.

Regional Distribution of ODA to Irrigation and Drainage

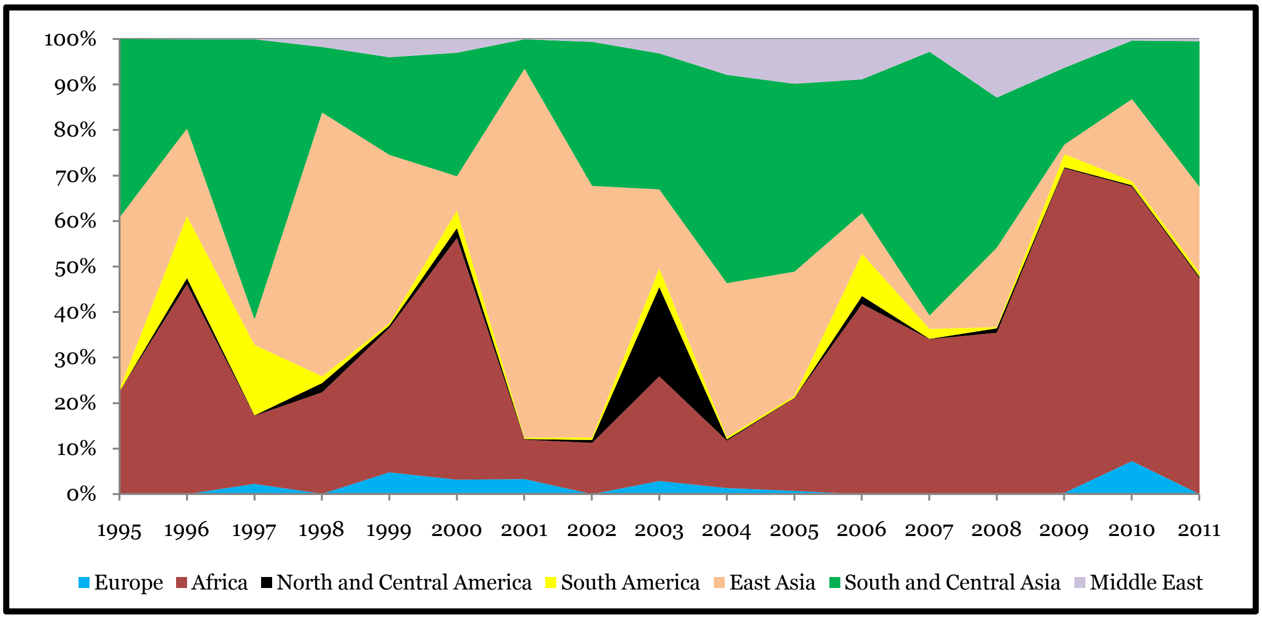
Whereas shares of South Asia and East Asia in lending to irrigation and drainage have remained strong in the declining ODA, Africa's share in irrigation has increased considerably in ODA to irrigation and drainage, is even larger than East or South Asia in some years, particularly since 2005 both in terms of amounts and shares. Much of this is formal irrigation with medium to small dams. It would seem that investing in high quality irrigation systems from the start in Africa would be important to avoid the vicious cycle of poor quality water service, lack of water charges, poor O&M, and more poor service discussed later.

Figure 20: Total ODA (Commitments) to Agricultural Water Resources* by Region (Current Prices) (USD billions) (1995-2011)



* The data on Agricultural Water Resources (i.e., Irrigation, reservoirs, hydraulic structures, ground water exploitation for agricultural use is available since 1995. Source: http://stats.oecd.org/Index.aspx?DatasetCode=TABLE5.

Figure 21: Percentage Share of Total ODA (Commitments) to Agricultural Water Resources* by Region (1995-2011)



* The data on Agricultural Water Resources (i.e., Irrigation, reservoirs, hydraulic structures, ground water exploitation for agricultural use is available since 1995. Source: http://stats.oecd.org/Index.aspx?DatasetCode=TABLE5.

Causes of Decline in ODA to Irrigation and Drainage

Early investment in water management in the 1970s was in the construction of new projects including dams and development of new irrigated lands. Dams have made a significant contribution to economic development with considerable benefits. Their water retention capacity over long periods of time is often critical to use water effectively, attenuate floods and alleviate impacts of droughts. They relieve drainage congestion, and when they work well dams provide for the timely and continuous supply of irrigation water needed to meet the demands of crops and livestock. Dams will continue to play an important role in the management systems. Although small dams cost more per unit of water stored, they can be more flexible, less costly in the long run since cost escalations and delays can be smaller.

Large dams have been controversial due in part to delays in construction and cost overruns which have been leading to declining rates of return. Other issues have included the adverse effects on local populations, displacement and involuntary relocation of peoples, and impacts on ecosystems and watersheds. Large dams have been criticized for fragmenting and transforming the world's rivers. World Resources Institute (WRI) notes that at least one large dam modifies 46 percent of the world's 106 primary watersheds (Earth Trends: The Environmental Information Portal).

For these reasons and public pressure, international institutions have been reticent about investing in large-scale dams since the mid-1990s after the Narmada Dam in India became the poster child, and led to the establishment of the Inspection Panel within the World Bank. Since then with a few exceptions, multilateral banks have started supporting mid-sized dams and rehabilitating existing dams instead (Boss hard 2013). International Commission on Irrigation and Drainage (ICID) and International Commission on Large Dams (ICOLD) have also developed criteria and guidelines pertaining to dams for their environmental impacts and their mitigation. Rehabilitation was far too often differed maintenance of irrigation systems. With the benefit of hindsight, perhaps the balance of past donor and national investments (e.g., in South Asia) have had far too much emphasis on physical infrastructure and not enough on policy, institutional and human infrastructure, and incentives for good performance, such that further investment in physical infrastructure (e.g., in India) would be a waste without investments in improved management.

Shift of International Assistance from Construction and Rehabilitation to Modernization

At early stages of the World Bank involvement in irrigation, the Bank did not finance rehabilitation. It rightly considered it to be the responsibility of recipient countries. Besides many of the rehabilitation projects did not deal with the underlying problems of poor policies, institutions, human capacity and incentives. Investing in rehabilitation without investment in technical and institutional modernization such as modern, high-tech gates and farmer WUAs and in other complementary investments such as training, incentives etc. limited impacts of past investments in irrigation. Failing to address the long overdue reforms of the poor management practices of the large irrigation systems should no more be acceptable; these shortcoming in irrigation for example have been identified , by irrigation experts within the World Bank in the 1970s and 80s and by external analysts such as Wade, Chambers and many others. They were never addressed because it was easy to demonstrate ex-post returns to investments were positive although lower than ex-ante estimates (IEG 2008). Yet steps to correct these weaknesses are long overdue. Indeed the failure to understand the links between the technical improvements of the large surface irrigation schemes and required reforms may exacerbate the problem of water scarcity and threaten food security in the future. Development of reliable irrigation in surface systems is crucial to realizing the challenge of irrigation. The importance and magnitude of investments and capacity building in human resources to achieve this goal is typically generally underestimated.[9] The result is the lack of timely availability of the needed quantity of water under farmer control.

Water Management Issue

Tushaar Shah notes that unlike in other irrigation systems India's surface irrigation was never intended to provide all the water needs of farmers rather than providing access to water as a drought proofing strategy to a large number of farmers. The growth of farmer financed tube wells in India is in part a result of the need for timely availability of water. He asserts that timely availability of water greatly reduces water use regardless of water pricing. And yet farmers have to be able to control the timing of water delivery, basically with water on their demand. The state of Gujarat has achieved this by ensuring timely supply of water and electricity to farmers, reducing water use, increasing productivity and improving ground water retention.

Additional Issues Surrounding Dams Relate to Downstream Issues

Production of hydroelectric power mostly for export creates conflict with local communities that need to produce food and assure livelihoods.

- Downstream areas are often highly dependent on irrigation and
- Social, economic, environmental factors play out in downstream areas from dams.

[9] http://www.fao.org/docrep/003/x6626e/x6626e05.htm.

As Chambers has so well articulated, downstream issues tend to be neglected, since impacts often occur after construction and during the less intensive operation phase of generating electricity (Chambers 2013). An estimated 472 million people are said to be impacted downstream by hydropower developments. "In terms of hydropower planning, these issues are not always captured in environmental and social studies due to their complex nature, and the time required to study and fully understand ecosystems and how different populations use and interact with them" (Sparkes 2013).

"When impacts are assessed, the starting point is often the optimal generation scenario for electricity production and the minimum or maximum water releases outlined in power purchase agreements (PPAs). This implies that the economic analysis of a particular project may be completed at the feasibility stage, before the complexity of downstream issues is fully understood" (Sparkes 2013).

Issues in Multiuse Dams

In addition, the water stored by dams is in demand by various sectors (for different uses) and this causes a question of water allocation. "The world's 45,000 large dams continue to cause conflict between providing hydropower, water supply, flood control, irrigation and other substantial benefits to many" (Moore, Dore and Gyawali 2010). In the year 2000, agriculture accounted for about 67 percent of water withdrawals, industry accounted for 19 percent, and municipal and domestic uses for 9 percent (World Commission on Dams 2000).

Financial Subsidies for Agricultural Water in Developing Countries

In the fast speed growth of WUAs in China, now numbering more than 50,000 WUAs and now covering about one-third of the irrigated area in 2008, the World Bank has played an important role. As a recent World Bank study notes, many WUAs, are not of high quality and only 40 percent are registered as an independent and permanent legal entity. WUAs face a common financial problem--their income is insufficient to cover their operation and maintenance (O&M) costs some 67 percent of WUAs nationwide suffer from financial difficulties "The lack of clear policies and regulations for setting end-canal water fees, similar to the current State water fee guidelines, generally results in insufficient water pricing to support adequate end-canal O&M and consequent financial difficulties for WUAs" (World Bank 2011). "Some WUAs, especially in the Northeast, have no end-canal water fee system at all, have no stable source of O&M funds and are therefore severely constrained financially" (World Bank 2011). "According to the farmer survey results, when the farmers' water fee expenditures account for more than about 5 percent of the agricultural output value, the farmers feel it is beyond their willingness to pay" (World Bank 2011). A CCCAP study notes that distribution entrepreneurs sometimes perform better than water users associations (Shah, Giordano and Wang 2004). This directly influences their operation and often threatens their very survival and sustainability. “Training and capacity building are key requirements for improved, standardized WUAs which provide large benefits to farmers and society and are needed to play an expanded and effective role in comprehensive water pricing. At present, no funds are included in government budgets for the training of farmers on WUAs or for the establishment of WUAs” (World Bank 2011).

China is not alone in financial difficulties of WUAs. In Armenia, water charges are determined and collected by area, and they account for only 27 percent of water supply cost. In Egypt, each year about US$5 billion are used as irrigation subsidies, and farmers do not need to pay water bills; they are only responsible for drainage and irrigation system maintenance in their fields. India’s annual subsidy for irrigation is about US$1.2 billion, and the overall price level is low, even the high charge rate is only about US$6 -7/ha. Indonesian farmers also do not need to pay water bills, as farmers are only responsible for the maintenance of irrigation systems in their fields. Since 1950s in Mexico, the annual irrigation system O&M costs accounted for 0.5 percent of its GDP. In Pakistan, subsidies for irrigation each year are about US$600 million, with diverse ways of charging issues. It is only in Moldova, that the government has covered all the cost of water supply.

Understanding Smallholder Irrigation in Sub-Saharan Africa

Africa is at an early stage of irrigation development, yet irrigated land contributes roughly 25 per cent to the value of agricultural output in SSA while occupying only 3.5 percent of the region’s cultivated land (Foster and Briceño-Garmendia 2009). Besides, experts argue without irrigation there would be no green revolution and no stability in Africa’s smallholder production and livelihoods (Cassman 2011). Besides, given the limited irrigation development in SSA, and the abundance of land and water resources, there is huge scope for expanding smallholder irrigation if the existing constraints can be overcome. Africa will face huge and growing pressures from population growth and food demand (Lele et al 2013c). Hence time is right to get Africa’s irrigation policy right from the start by African policymakers and donors learning lessons from Asia. Getting it right in Africa has several possible strategic choices. The first is about the choice of technology and scale. Those with knowledge of British and American and French engineering, including co-authors of this paper, believe the French irrigation technology is superior to the British colonial heritage. This issue of technology and management systems needs more critical assessment. The second strategic choice relates to scale, the extent to which countries should rely on dams as against small informal irrigation systems. The third and critical set of issues relate to governance. It is clear that democratic governance such as the one in India has been less suited to adherence to formal rules and regulations of a command and control system than is perhaps true of the more authoritarian systems of China and Morocco and the one that existed in the immediate post-colonial period in India. More recently these authoritarian systems have been complemented by incentives for farmers to act through communities using water users' associations. Surprisingly democratic India has made less progress in farmer participation in which participation is accompanied by responsibility and accountability for results unlike in the more authoritarian systems. Like in Asia, Africa's irrigation history has a large colonial imprint and many of the formal irrigation projects in Africa face some of the same issues of poor design and implementation, high costs, poor operations and maintenance and need for rehabilitation. Besides, like in Asia, informal irrigation is growing, perhaps also reflecting governance challenges. To capture that experience a study of smallholder irrigation in the region of Sub-Saharan Africa was undertaken in 2011 by Shah et al, using case studies from nine countries: Mali, Niger, Nigeria, Ghana, Burkina Faso, Ethiopia, Kenya, Tanzania, and Malawi. The study notes that "The overarching assumption in the design of the survey was that smallholders desire irrigation to improve on-farm water control; and that the degree of such water control depends on the mode of irrigation defined by the water source and the technology of water mobilization and conveyance" (Shah et al 2013).

"Since the 1980's vibrant pockets of informal smallholder irrigation have emerged throughout SSA, supported sometimes by NGOs and donors, using manual or motorized pumps to lift small amounts of water from above or below ground to irrigate garden as well as field crops" (Shah et al 2013).

"These smallholder schemes depend for water on shallow wells, ponds, streams, rivers and other sources; they often involve lifting by manual or motor pump and conveyance of water through open channels or pipes" (Shah et al 2013).

Case studies saw the emergence of "a new entrepreneurial model of irrigation organization in which the smallholder was the decision maker rather than a laborer; technology used was familiar and affordable; and institutional arrangements promoted farmer management, either in groups or individually" (Shah et al 2013).

"Small-scale irrigation is not large-scale formal irrigation made small. It is perhaps in the management element that the key difference lies. In a small system there are no tiers of management as in large-scale schemes. The farmer alone decides when to irrigate and how much water to apply, when to start and stop pumps or other appliances, and generally runs the entire scheme with the help of the family or local community members" (Shah et al 2013).

"Manual irrigation, using human labor, is characterized by its low capital investment which ranges from US $15 for a bucket (used by a large number of our sample farmers in the Upper-East Region of Ghana, Burkina Faso, Niger and Mali) up to US $150 for high-end treadle pumps coupled with overland flexible pipes (found mostly in Tanzania)" (Shah et al 2013). Most manual pump irrigation was found to be profitable.

"Our surmise was that motor pump owners enjoy the same level of water control as manual lift irrigators but would be able to bring larger areas under garden crops per family farm worker compared to manual irrigators who have to divide their labor between tending crops and fetching water" (Shah et al 2013). "While pump irrigation does not automatically and always translate into higher land or labor productivity compared to gravity flow irrigation, it does inspire confidence in farmers to intensify more, take greater risks and open up to the market" (Shah et al 2013).

"Among the constraints facing gravity flow irrigators, therefore, 'insufficient water availability' featured prominently, along with 'working capital shortage', 'land scarcity' and 'shortage of family labor'. Somewhat surprisingly, 'high water fee' did not seem to bother our sample gravity flow farmers even in West African locales where canal water rates are relatively high" (Shah et al 2013).

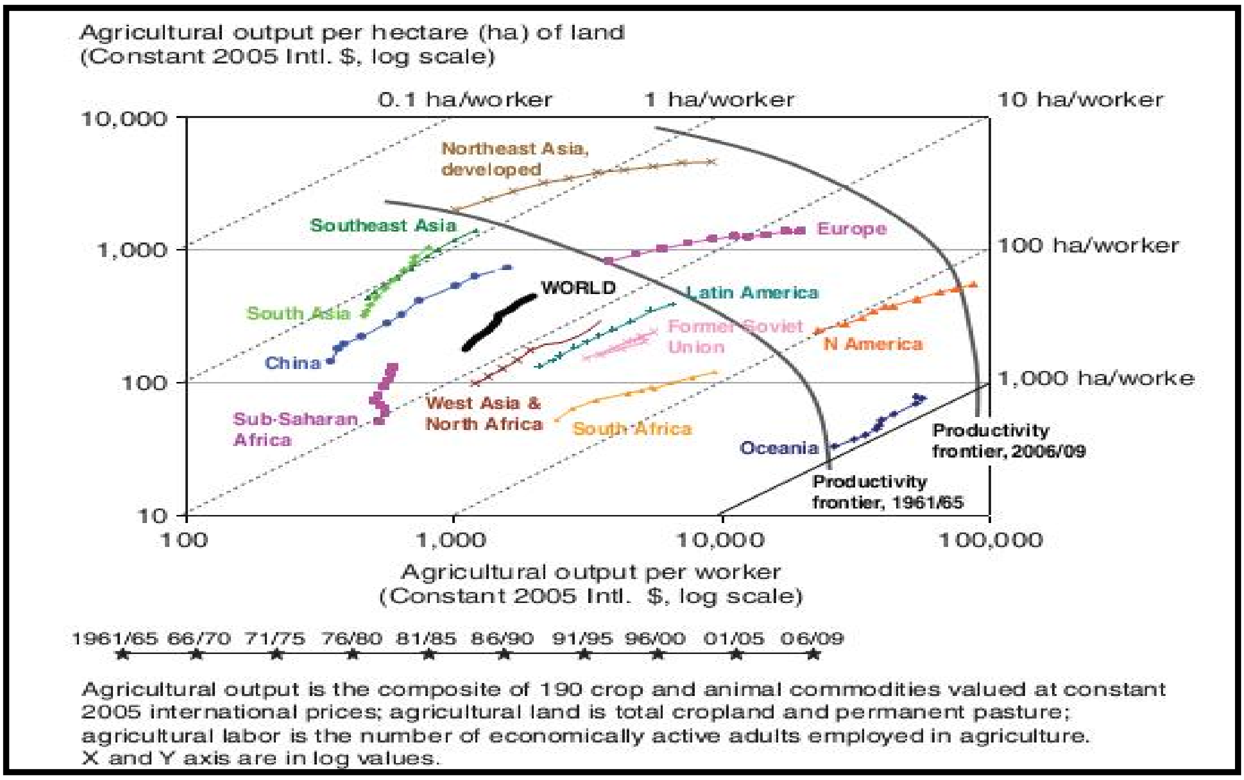
Implications of the Evidence to Date Going Forward

Projecting from the past trends in productivity growth the Global Harvest Initiative concludes that under business as usual, if present trends continue, all regions with the exception of Latin America will be experiencing a food gap due to increases in population and food demand, unless productivity in each of the regions increases. The gap that needs to be filled is the greatest in South Asia and Sub-Saharan Africa.

This calls for increasing total factor productivity in agriculture. We have purposely stressed the importance of total factor productivity because specialists have a tendency to look at partial measures of productivity, e.g., land productivity, as measured in yields per hectare, which may be achieved without increasing water productivity as measured in crop per drop, or labor productivity as measured in output per worker, and fertilizer productivity as measured in kilograms of output per kilogram of fertilizer. Total factor productivity stresses that investments are needed in all factors of production as well as in increasing the access of producers to markets to achieve growth. The slow growth in total factor productivity in the past was the result of imbalanced investments, too much investment in hardware, e.g., in irrigation projects and not enough in the software to improve outcomes.

Figure 22 below shows the vast difference in productivity among developed and developing countries, and within the developing world, with agricultural output per worker on the x axis and agricultural output per worker on the y axis. The curve closest to the origin shows developing country productivity and that to the right is the productivity per worker in developed countries. The challenge is to get from here and now to where developed countries are today.

Figure 22: Agricultural Land and Labour Productivity Has Steadily Improved Since 1960, But Developing Countries Lag Decades Behind Developed Countries As Well As Among Themselves



Source: Fuglie et al (2012) using data from the Food and Agriculture Organization of the United Nations.

Our Review of the Irrigation Systems in the Developing World Leads Us to the Following Key Recommendations:

1. Develop a reliable data system for water resources and make information public;

2. Institute a transparent system of performance benchmarking not just for the public irrigation systems but benchmarking of their management. Identify lessons for the poor performing systems of Asia and Africa.

3. Establish a performance management culture in public irrigation systems;

4. Raise Irrigation Service Fees (ISF) increasing them closer to the marginal value product of irrigation;

5. Improve ISF collection to 80-90 per cent of the assessment; ensure that the operating turn-over of an irrigation system is at least 10-12 percent of capital investment;

6. Establish and levy a 'conjunctive use' charge on groundwater irrigation within the command area (especially in Asia where groundwater use within command areas is rampant);

7. Link Operation and Maintenance budgets of irrigation systems to their Irrigation Service Fee collection performance;

8. Provide system managers strong incentives to organize Water User Associations, enter in to service contracts with WUAs and allow WUAs to retain a portion of ISF collection for repair and maintenance of the distribution system;

9. Hive off successful irrigation systems as autonomous farmer irrigation companies with perhaps contracts with private sector for delivery of produce;

10. Undertake the actions needed to improve irrigation service delivery, including the management of the main and delivery systems which includes:

a. Design of the overall modernization program for both hardware and software integrated together, starting with initial assessment.

b. Use technical performance diagnostic tools such as RAP and MASCOTTE.

c. Promote training in modernization at ALL levels including academics, training institutes, consultants, contractors, governments, project managers, systems operators.

d. Combine design and Implementation of modernization and rehabilitation to avoid adoption of outdated and/or inadequate standards and ultimately operational procedures.

Beginning with these changes and intensifying them where they have already been underway, would attract more public and private investment, including farmer resources to water management and improve prospects for sustainable and equitable use of water resources in agriculture.

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