Sustainability of Groundwater in South Asia: Need for Management through Institutional Change

Mr. Achiransu Acharyya*

Introduction

One of the objectives of the Millenium Development Goals is to 'ensure Environmental Sustainability through integration of the principles of sustainable development into country policies and programs reversing the loss of environmental resources'. (Goal 7A of MDG) In most of South Asia, while property rights to land are generally clearly defined, rights to water are not. Hence water is an open access resource, a kind of free good that is not treated as an economic input. It is usually assumed that owners of the land become owners of the water below or in the vicinity of the land. It is perhaps for this reason and because of the ill defined property rights to ground water, treating it as a free good, that the role of water has been relatively ignored while providing for explanations of the agricultural growth in South Asia.

However, irrigation has always played a central role in the agrarian economy of Asia, from supporting famed hydraulic civilizations in the ancient past to spearheading Green Revolution in the 1960s and 1970s. Asia accounts for 70% of the world's irrigated area and is home to some of the oldest and largest irrigation schemes (Molden, 2007). While these irrigation schemes played an important role in ensuring food security for billions of people in the past, their current state of affairs leaves much to be desired.

The purpose of this paper is to analyze the current trends in irrigation in South Asia and suggest ways and means for revitalizing irrigation for meeting our future food needs and fuelling agricultural growth. This paper is divided into five sections. Section 2 discusses the serious problem of irrigation and in general ground water resource scarcity across South Asia. Section 3 looks upon the impact of climate change on groundwater resources across South Asia. Section 4 proposes a theoretical framework for adaptation to climate change from resulting water scarcity. Section 5 discusses the different institutional alternatives of adaptation for sustainability of groundwater resources in South Asia as well as ensuring food security. Section 6 is the concluding section.

The Crisis of Water Resources in South Asia

While irrigation has been central to the agricultural economies of South Asia (Fig 1), the sector is under serious threat due to a number of reasons.

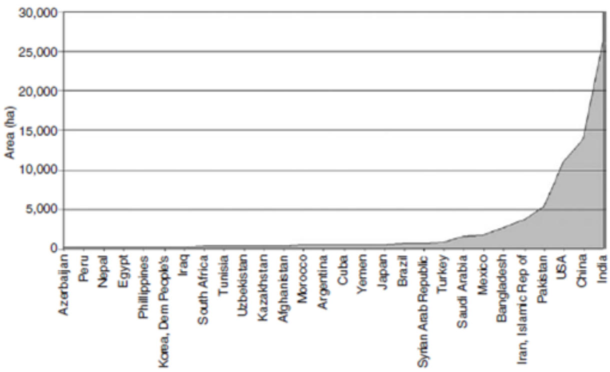


Fig 1. Groundwater-irrigated area in countries with intensive groundwater use in agriculture. (From Food and Agricultural Organization, 2003.)

For one, more and more countries of South Asia face the threat of physical water scarcity and those who do not, are crippled by economic scarcity of water. Surface irrigation infrastructure has deteriorated due to lack of maintenance which often is a reflection of changing requirements of farmers that gravity flow irrigation can no longer provide. Crop diversification away from rice and wheat means that gravity irrigation structures constructed keeping in mind cereal crops do not readily adapt themselves to a more diversified cropping pattern that farmers in Asia are now moving towards. Massive efforts towards rehabilitation and more recently

*Assistant Professor, Department of Economics, Visva Bharati University, Santiniketan West Bengal. Article based on the paper presented at the International Conference held at JKSHIM, Nitte on December 29-30, 2012.

towards modernization of gravity flow systems have yielded less than satisfactory results. Irrigation reforms in the form of irrigation management transfer (IMT) or participatory irrigation management (PIM) have failed to deliver the promise of better and efficient delivery of irrigation services in South Asia. Increasingly, farmers in South Asia are turning to groundwater irrigation (Fig 2) which gives them a greater control over use of water.

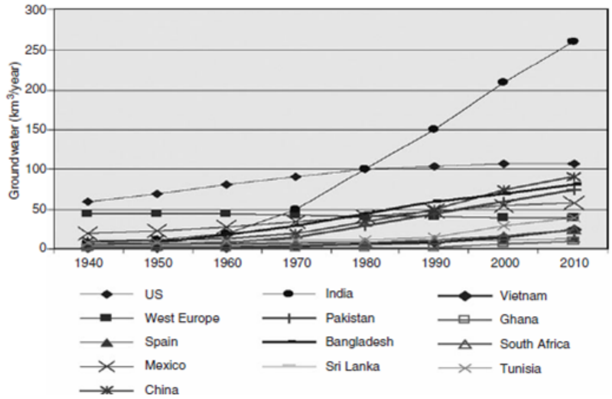


Fig 2. Growth in groundwater use in select countries (FAO 2003)

Groundwater boom, while bestowing a large number of benefits, have created its own set of intractable problems in terms of over-exploitation and depletion of groundwater resources thereby putting in jeopardy the livelihoods of millions of farmers who depend on it. Globalization, urbanization, climate change, competing demands for water, changing aspirations, renewed emphasis on environmental water needs and the need to keep feeding millions of people in South Asia continue to offer great challenges to the irrigation and drainage sector. There are major reasons for this groundwater dependency by farmers in South Asia. These are as follows:

Underperformance and Shrinkage of Large Scale Surface Irrigation Systems

Of all the regions in Asia, it is South Asia, where the problem of underperformance of irrigation systems has taken an epic proportion. Between 1994 and 2003, India and Pakistan together lost more than 5.5 million hectares (ha) of canal irrigated area, despite, very large investment in rehabilitation of existing canals and construction of new ones. This is due to poor functioning of these systems which forces the farmers to opt out and invest in their own irrigation sources. Even otherwise, productivity (both land and water) in far too many of these large scale surface irrigation scheme all across Asia is abysmally low (Molden et al. 1998),

Moving from Centralized Gravity Flow Systems to Individual Lift-Based Irrigation

While Asia's large scale surface irrigation schemes continues to under-perform, total area under irrigation is on the rise everywhere in South Asia. This is due to the rise of individualistic groundwater based irrigation fueled by cheap pumps and often supported by government subsidies in the form of cheap electricity. This 'water scavenging' irrigation, as it is often called (Shah 2008) is most visible in South Asia and in drier North China plains, but is on rise even in wetter parts of South Asia (Mukherji et. al. 2009). For instance in India there has been a transition from surface irrigation to groundwater based irrigation over the last few decades (Table 1) (Fig 3 and Fig 4)

Year	Canal	Tanks	Tube Wells	Other Wells	Total Wells	Other Sources	Total Net Irrigated Area
1950-51	8295	3613	0	5978	5978	2967	20853
1960-61	10370	4561	135	7155	7290	2440	24661
1970-71	12838	4112	4461	7426	11887	2266	31103
1980-81	15292	3182	9531	8164	17695	2551	38720
1990-91	17453	2944	14257	10437	24694	2932	48023
1995-96	17120	3118	17894	11803	29697	3467	53402
2000-01	15710	2518	22324	11451	33775	2831	54833
2001-02	15877	2336	22816	12020	34836	2827	55876
Percentage Share of Various Sources							
1950-51	39.78	17.33	0.00	28.67	28.67	14.23	100
1960-61	42.05	18.49	0.55	29.01	29.56	9.89	100
1970-71	41.28	13.22	14.34	23.88	38.22	7.29	100
1980-81	39.49	8.22	24.62	21.08	45.70	6.59	100
1990-91	36.34	6.13	29.69	21.73	51.42	6.11	100
1995-96	32.06	5.84	33.51	22.10	55.61	6.49	100
2000-01	28.65	4.59	40.71	20.88	61.60	5.16	100
2001-02	28.41	4.18	40.83	21.51	62.35	5.06	100

Table. 1 Sources of Irrigation in India: 1950-51 to 2001-02 ('000 Hectares)
Source: Central Ground Water Board, India (2003)

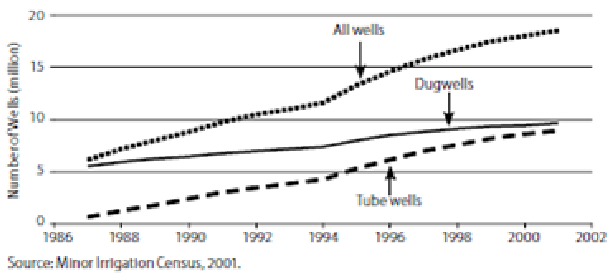


Fig. 3 Sources of Irrigation in India 1986 to 2001-02

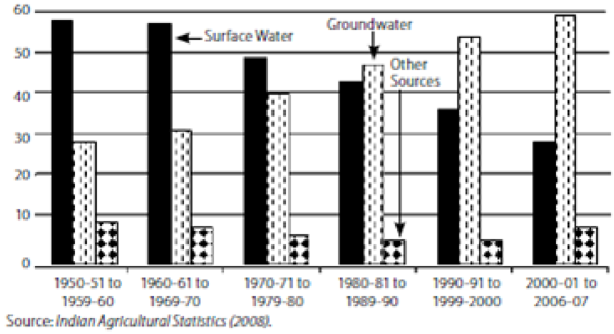


Fig. 4 Growth of groundwater use in India (1950 - 2006-07)

What pump irrigation is able to do, but large scale public systems are unable to match, is to provide farmers with water in timely and reliable manner to enable them to grow a wide variety of crops that caters to new market demands that farmers face. But this onslaught of groundwater irrigation has brought home its own set of intractable problems such as groundwater over-exploitation (Table 2 shows the aquifer depletion of blocks of different states in India) and rapid quality deterioration - thereby calling into question the long term sustainability of such an informal irrigation economy.

		Number of Districts	Number of Block/ Taluka/ Watershed	Overexploited		Dark/Critical		Year
				Num ber	Per- cent	Num ber	Per- cent	
1	Andhra Pradesh	22	1157	118	10.2	79	6.8	2001
2	Arunachal Pradesh	3		0	0.0	0	0.0	1998
3	Assam	23	134	0	0.0	0	0.0	2001
4	Bihar	42	589	6	1.0	14	2.4	2002
5	Chhatisgarh	16	145	0	0.0	0	0.0	1998
6	Goa	3	12	0	0.0	0	0.0	1998
7	Gujarat	20	184	41	22.3	19	10.3	1997
8	Haryana	17	108	30	27.8	13	12.0	2002
9	Himachal Pradesh	12	69	0	0.0	0	0.0	1998
10	Jammu & Kashmir	14	123	0	0.0	0	0.0	2002
11	Jharkhand	13	193	0	0.0	0	0.0	2002
12	Karnataka	19	175	7	4.0	9	5.1	1998
13	Kerala	14	154	3	1.9	6	3.9	1999
14	Madhya Pradesh	45	459	2	0.4	1	0.2	1998
15	Maharashtra	29	231	0	0.0	34	14.7	1998
16	Manipur	6	26	0	0.0	0	0.0	1998
17	Meghalaya	5	29	0	0.0	0	0.0	1998
18	Mizoram	3	20	0	0.0	0	0.0	1998
19	Nagaland	7	21	0	0.0	0	0.0	1998
20	Orissa	30	314	0	0.0	0	0.0	1999
21	Punjab	17	138	81	58.7	12	8.7	2002
22	Rajasthan	32	236	86	36.4	80	33.9	2001
23	Sikkim	4	4	0	0.0	0	0.0	1998
24	Tamil Nadu	27	385	135	35.1	35	9.1	1998
25	Tripura	3	17	0	0.0	0	0.0	2001
26	Uttar Pradesh & Utranchal	74	822	2	0.2	20	2.4	2000
27	West Bengal	16	341	0	0.0	61	17.9	2002
28	UTs		20	5	25.0	2	10.0	1998
	All India	516	6106	516	8.5	385	6.3	
Unit of Assessment: Andhra Pradesh, Maharashtra: Watershed; Gujarat, Karnataka: Taluka; Rest of the states-Blocks								
Over-exploited: >100%; Dark: >85% - <100%								
Source: Central Ground Water Board 2003.								

Table 2: Critically exploited groundwater resources of different blocks of states in India (CGWB 2003)

The high energy consumption of lift based irrigation systems as compared to gravity flow systems also makes long term sustainability an issue. Such a deep structural change in irrigation sectors composition, also calls for a paradigm shift in our thinking on irrigation.

Failed Attempts at Irrigation Sector Reforms

Concerned with the poor performance of irrigation systems, donors and governments in Asia had embarked upon a path of institutional reforms way back in the 1980s. Poor operation and deferred maintenance was diagnosed as a problem resulting from lack of involvement of farmers in management decisions. This resulted in policies aimed at increasing farmers' stake in day to day management of irrigation systems through Participatory Irrigation Management (PIM). However PIM had failed for various reasons.

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

All the above problems have led farmers to over depend on groundwater resources using private investment for agriculture. However, the overdependence on groundwater for irrigation purposes by the farmers has led to a serious depletion of the resource in South Asia. For instance, according to the report of the Central Ground Water Board (2011) in India, most of the states in the country have a critical groundwater condition, which implies that the rate of annual groundwater recharge is falling (Table 2). Moreover, Climate change is expected to significantly alter South Asia's hydro climatic regime over the 21st century. (IPCC Report, 2001) Added to this is the menace of arsenic and fluoride contamination in India and Bangladesh. Hence it is important to develop a policy whereby farmers adopt different irrigation technologies in response to climate change mainly on precipitation, temperature and water availability like watershed management and rainwater harvesting in order to have a sustainable groundwater extraction without depleting the resource.

Climate Change Impacts on Groundwater in South Asia

Climate change is expected to signi?cantly alter South Asia's hydro-climatic regime over the 21st century. It is widely agreed that the Indo-Gangetic basin is likely to experience increased water availability from snow-melt up to around 2030 but face gradual reductions thereafter. Parts of the Indo-Gangetic basin may also receive less rain than in the past; but the rest of India is likely to bene?t from greater precipitation. According to IPCC (2001), most Indian landmass below the Ganges plain is likely to experience a 0.5-1 ?C rise in average temperatures during 2020-2029 and 3.5-4.5 ?C rise in 2090-2099. Many parts of peninsular India, especially the Western Ghats, are likely to experience a 5-10% increase in total precipitation (IPCC 2001); however, this increase is likely to be accompanied by greater temporal variability. Throughout the sub-continent it is expected that 'very wet days' are likely to contribute more and more to total precipitation, suggesting that more of India's precipitation may be received in fewer than 100 ha of thunderstorms-and half in less than 30 ha-as has been the case during recent decades. This is likely to mean higher precipitation intensity and larger number of dry days in a year. Increased frequency of extremely wet rainy seasons (Gosain and Rao 2007) is also likely to mean increased run-off. According to Milly et al (2008), compared to 1900-1970, most of India is likely to experience 5-20% increase in annual run-off during 2041-60. All in all, India should expect to receive more of its water through rain than through snow; get used to snow-melt occurring faster and earlier; and cope with less soil moisture in summer and higher crop evapotranspiration (ET) demand as a consequence.

To the extent that climate change results in spatial and temporal changes in precipitation, it will have a strong in?uence on natural recharge. Moreover, since a good deal of natural recharge occurs in areas with vegetative cover, such as forests, changing evapotransporation rates resulting from rising temperatures may reduce in?ltration rates from natural precipitation and thus reduce recharge. Recharge responds strongly to temporal pattern of precipitation as well as soil cover and soil properties. If climate change results in changes in natural vegetation in forests or savanna, these too may in?uence natural recharge; however, the direction of the net effect will depend upon the pattern of changes in the vegetative cover. Simulation models developed by Australian scientists have showed that changes in temperatures and rainfall in?uence growth rates and leaf size of plants that affect groundwater recharge (Kundzewicz and Doll 2007). The direction of change is conditioned by the context: in some areas, the vegetation response to climate change would cause the average recharge to decrease, but in other areas, recharge to groundwater would more than double. Changing river ?ows in response to changing mean precipitation and its variability, rising sea levels and changing temperatures will all in?uence natural recharge rates (Kundzewicz and Doll 2007)[1]

We know little about how exactly rainfall patterns will change, but increased temporal variability seems guaranteed. This will mean intense and large rainfall events in short monsoons followed by long dry spells.

[1]http://www.gwclim.org/presentations/plenary/kundzewicz.pdf.

All evidence we have suggests that groundwater recharge through natural in?ltration occurs only beyond a threshold level of precipitation; however, it also suggests not only that run- off increases with precipitation but the run-off coefficient (i.e. run-off/ precipitation) itself increases with increased rainfall intensity (or precipitation per rainfall event) (Carter 2007). Higher variability in precipitation may thus negatively impact natural recharge in general. What will be the net impact on a given location will depend upon the change in both the total precipitation and the variability of that precipitation.

The Indo-Gangetic aquifer system has been getting heavy recharge from the Himalayan snow-melt. As snow-melt-based run-off increases during the coming decades, their contribution to potential recharge may increase; however, a great deal of this may end up as 'rejected recharge' and enhance river ?ows and intensify the ?ood proneness of eastern India and Bangladesh. As the snow-melt-based run-off begins declining, one should expect a decline in run-off as well as groundwater recharge in this vast basin[2].

A major interplay of climate change and groundwater will be witnessed in coastal areas. Using the records of coastal tide gauges in the north Indian Ocean for more than 40 years, Unnikrishnan and Shankar (2007) have estimated a sea level rise between 1.06 and 1.75 millimetre (mm) per year, consistent with the 1 to 2 mm per year global sea level rise estimates of IPCC. Rising sea levels will threaten coastal aquifers. Many of India's coastal aquifers are already experiencing salinity ingress. This problem is particularly acute in Saurashtra coast in Gujarat and Minjur aquifer in Tamil Nadu. In coastal West Bengal and Bangladesh, Sundarbans (mangrove forest) are threatened by saline intrusion overland, affecting its aquifers. The precarious balance between freshwater aquifers and sea water will come under growing stress as sea levels rise. Coastal aquifers are thus likely to face serious threats from climate-change-induced sea level rise.

Some scientists suggest climate change may alter the physical characteristics of aquifers themselves[3].

Farmer's Adaptation to Climate Risk in the Context of South Asia

Since farmers are sensitive and exposed to a range of climatic and non-climatic forces which do not act in isolation of each other (Reid et. al. 2007), systematic analysis method has been introduced to explore the complicated relationship between climate change and farmer's adaptation. Vulnerability theory is such a kind of method. Vulnerability is such a concept that was mentioned in different research traditions (Galllopin 2006). Research on vulnerability to the impacts of climate change spans all the antecedent and successor traditions (Adger 2006), because it is explicitly referred to in the United Nations Framework Convention on Climate Change where commitments are made by countries to promote adaptation to address vulnerable regions and peoples (Ford et. al. 2006).

In order to target the vulnerable regions and peoples, many indicators and measurement methods have been explored. One of the most influential and widely-used components is the one defined by IPCC, and it includes exposure, sensitivity and adaptive capacity (Ford et. al. 2006). Exposure in this case is the magnitude and duration of the climate-related exposure such as a drought or change in precipitation, sensitivity is the degree to which the system is affected by the exposure, and adaptive capacity is the system's ability to withstand and recover from the exposure (Ebi et. al. 2006).

For the relationship, Ford et al. (Ford et. al. 2006) believe that exposure-sensitivity is dependent upon both the characteristics of climatic conditions and the nature of the community in question which varies among groups of the community; adaptive capacity is dynamic, varying over space and time with the characteristics of the human system; the range of technology available for adaptation may enable exposure to be managed while the same technology may also affect risk evaluation strategies and result in more risk taking behavior. Based on the experimental research in Africa, (Hahn et al.2009) gives some further major sub-components and indicators, such as Socio-Demographic Profile, Livelihood Strategies, Social Networks, Health,

[2]Monitoring data on Himalayan glaciers present a confusing picture. They indicate recession of some glaciers in recent years, but the trend is not consistent across the entire mountain chain (Singh and Arora 2007).

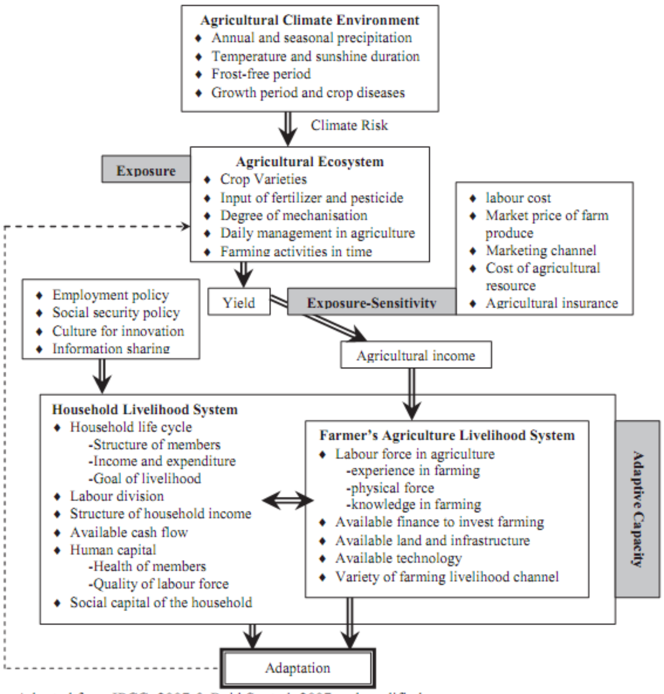
[3]Aquifers are also of interest to climate researchers for other reasons. Growing literature on carbon capture and storage (CCS) and geological sequestration hints at opportunities that aquifers-especially saline and otherwise unusable-offer as 'carbon storehouses'. This paper, focusing on climate change-groundwater agriculture interaction, does not deal with these aspects.

Food, Water and Natural Disasters and Climate Variability. Multiple factors including broad-scale and local factors have been approved to affect vulnerability too.

Depending on the scale of the target group, vulnerability concept can be applied in different levels including the state level, the institutional level, community level and farmer level. Top-down approach and bottom-up approach are two different modes for assessing vulnerability perspective. Since farmers are the first actor confronting the change of climate and farming system change, it is necessary to understand and gather farmer's perception and adaptation to climate changes.

Adaptation is a process of deliberate changes, often in response to multiple pressures and changes that affect people's lives, and successful adaptations may be viewed as those actions that decrease vulnerability and increase resilience overall, in response to a range of immediate needs, risks and aspirations (Stringer et. al. 2009). In order to create a harmonious environment both internal and external; and to invest in social adaptation, it will be very favorable to identify the precise drivers and determinants and understand the strategic process of adaptation at farm-level.

The conceptual framework employed in the study has been shown in Figure 5. Agricultural climate risks are embedded in a series of changes in agricultural climate environment. These risks have been exposed to agricultural ecosystem and a combination of forces in social dimension takes place dependently, which can be called "farmer's exposure-sensitivity". Farmer's agricultural income becomes changeable and finally farmer' vulnerability occurs. As agriculture is part of farmer household's livelihood system and farming risk is usually shared within the members of the whole family, farmer's adaptation is interlinked not only to the agricultural system, but also to the off-farm activities and human, social capital of the household. After deep consideration of all the surrounding factors such as; social, environmental and economical, farmers continues for adaptation to changes, which can also bring new risky opportunities for them.



Source: Adopted from IPCC, 2007 & Reid S. et al. 2007 and modified

Fig. 5: Conceptual Framework of Farmer's Adaptation to Climate Risk

Farmer's adaptation to exposure-sensitivity

To cope with the losses caused by climate risk and to reduce the possible same losses in future, farmers take different movements to adapt the exposure-sensitivity. There are two ways of farmer's adaptation to exposure-sensitivity, firstly, through new livelihood channels in off-farm/non-farm area and secondly, through adaptive innovation in the crop farming system.

Seeking New Livelihood Channels

The common and easy way in off-farm area is to completely or partly give up agriculture and the whole or part of the family members become migrant workers or so called employed farmers. Agriculture then becomes an abandoned occupation. Some farmers believe that the structure of planting has been formed and when the climate risk happens, they would like to do some part-time work to compensate the losses caused by climate risk. There are also some farmers who are forced to learn some new skills suitable and available in order to continue crop-farming.

Adaptive Innovation in Crop Farming System

More efforts and inputs are given in the crop farming system. The adaptation in crop farming system can be divided into three parts including in pre-risk, during risk and post-risk.

Pre-risk Adaptation

In pre-risk, collective actions are more tending to good infrastructures of irrigation and drainage; meanwhile professional officers in the Ministry also deliver some guidelines in the form of news on climate risk such as when the meteorological information has shown the tendency of occurrence of plant diseases and insect pests, the guideline would tell the farmers to use pesticides to prevent the risk. After consideration of the previous year risk factors and farmer's own experience, as well as the collected information, individual households take varieties of adaptations such as crop diversification, using different crop varieties, reallocating the crop land area, changing the planting and harvesting dates, drought-resistant varieties and high-yield water sensitive crops. Generally speaking, varieties of crop planting is an effective way to reduce climate risk, but so far as the poor farmers of South Asia are concerned, only the medium-size households would take such measures, since the food security is the basic principle of small farmers and convenient employment with less cost is the goal of those farmers who have a large family.

During Risk Adaptation

During climate risk, some farmers have taken more time on observing the crops, for instance, when new hazards happen, they would take available measures like replanting seedlings in drought season, artificial drain in excessive precipitation and more pesticide in plant diseases and insect pests. There are also some farmers who would do nothing during the risk since they believe that much input on agriculture can't guarantee the good harvest or better income. The uncertainty of climate changes causes them to make such a decision.

Post-risk Adaptation

For post-risk adaptation, some farmers exchange their experiences with other surrounding farmers through social capital. A few of farmers begin to do some experiment on new technology like the new crop variety in a small plot. By comparing crop profits in paddy land and dry land, some farmers change their dry land to paddy land. Since less output is required for Winter Crop unlike Summer Crop, some farmers change the farming system of one-year double-crop planting into one-year one-crop.

Most farmers realize that the climate risk is an increasingly important factor in present agricultural system and they indeed have a demand for and need agricultural insurance. However, famers who have agricultural insurance most often do not get any compensation because of the unreasonable cost-benefits of the institutional arrangement. The validity and effectiveness of the institution have restricted farmers' behavior and make them just waiting. Under the circumstamces, most farmers might make the decision on adaptation just for short-term period like two or three years just to cope with the forthcoming climate hazards. For the systematic risk management in long-term, it would still need more external supports financially and technically.

Alternative Institutions for Sustainability of Groundwater Resources in South Asia

Asia's population will reach 5 billion by 2050. How much more food would we need by then? Table 3 provides projection on future food demand for South, East and Central Asia4.

Table 3: Food supply projections for Asia (million metric tons) (Source: De Fraiture 2009)

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

Includes food, feed and other uses

Feeding 1.5 billion additional Asian people by 2050 will require water development and management decisions that address tradeoffs between food and environmental security as also address the bigger question of sustainability of groundwater resources.

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

Strategies for South Asia

Re-engineering or modernizing canal systems to mimic flexibility inherent in groundwater irrigated systems is the top investment priority in the region. This would involve a number of interventions; both hardware (physical) and software (capacity building).One of the main objectives in this context would be storage of rainwater through rainwater harvesting and aquifer recharge through watershed management. Some of the suggested option would be unbundling of irrigation services much on the lines of unbundling of electricity utilities in the region, use of piped delivery from tertiary and below tertiary level, better measurement at all levels, construction of farm level storage ponds to increase flexibility and re-orientation of canal bureaucracy towards better service delivery. In areas of physical water scarcity, there is huge potential for using precision irrigation and micro irrigation technologies and the time to promote them is now. Investing in managed aquifer recharge will help in controlling groundwater over-exploitation in the region. Farmers across South Asia are investing in supply augmentation through unplanned and ad hoc recharge. The question is: can this be done systematically and how? In addition, much of the important investments will lie outside the irrigation sector. For example, investment in rural electrification and reforming the electricity sector will have a much higher impact on groundwater use than any groundwater regulation will ever have. Investment in rural roads and markets too would be crucial given the move towards diversification of agriculture in India and other countries in the region.

Modernize Yesteryear's Schemes for Tomorrow's Needs

In Asia, most irrigation schemes were built before the 1970s, and have operated for 40 years and more and now needs to be modernized - both technically and institutionally, for example by being redesigned, operated and managed for a range of uses. Smart irrigation technologies, both old and new, will be essential to meet changing demands. For example, surface irrigation schemes could be used to recharge aquifers or fill intermediate storage structures, such as farm ponds, providing farmers with greater

4South Asia: India, Afghanistan, Bangladesh, Nepal Pakistan, Sri Lanka reliability and control. Meanwhile institutional changes that lead to flexible and responsive management will be vital for mitigating against, and adapting to, climate change.

Go with the Flow By Supporting Farmers' Initiatives

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

Look beyond Conventional Participatory Irrigation Management (PIM) / Irrigation Management Transfer (IMT) Recipes

Efforts to reform large-scale irrigation schemes by transferring management to farmers have had less-than-expected success throughout Asia. Many believe that the private sector could help irrigation entities improve water delivery, but it needs to be tested. For example, irrigation departments could outsource irrigation services, create public-private partnerships or provide incentives for irrigation officials to act as entrepreneurs in publicly managed operations. The roles government and the private sector would play in maintaining and operating irrigation systems should be clearly defined. There is a need for increasing accountability of the irrigation staff towards their clients (farmers) and for this purpose; there is a need for formulating better irrigation performance benchmarks.

Boost Knowledge through Training

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

Invest Outside the Irrigation Sector

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

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

Conclusion

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

The nature of the challenge will determine the extent to which the existing systems can be adapted to the future needs. For example, reliability and timeliness of irrigation water supply will be crucial in ensuring both increased food grains production and high value crops. In addition, for high value crops, on demand pressurized irrigation systems would be at premium.

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

References

Adger W.N. 2006 'Vulnerability, Global Environmental Change', 16: 268-281.

Carter R C 2007 'Climate, population and groundwater in Africa', Int. Conf. on Groundwater and Climate in Africa (Kampala, June2008)

Central Ground Water Board, Annual Report. 2003. India.

Central Ground Water Board, Annual Report. 2011. India.

De Fraiture, C. 2009, 'Scenarios of water and food in Asia', Background Paper # 2, submitted to Asian Development Bank, October 2009.

De Fraiture, C., Wichelns, D., Rockström, J., Kemp-Benedict, E., 2007. 'Looking ahead to 2050: Scenarios of alternative investment approaches'. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture. Earthscan, London; International Water Management Institute, Colombo.

Ebi K.L., R.S. Kovats and B. Menne 2006 'An approach for assessing human health vulnerability and public health interventions to adapt to climate change', Environmental Health Perspectives, 114:1930-1934.

Ford J.D., B. Smit and J. Wandel, 2006, 'Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada', Global Environmental Change, 16:145-160.

Galllopin G.C. 2006, 'Linkages between vulnerability, resilience and adaptive capacity' Global Environmental Change, 16:293-303.

Gosain A K and Rao S 2007 'Impact assessment of climate change on water resources of two river systems in India' Jalvigyan Sameeksha 22 21

Hahn M.B., A.M. Riederer and S.O. Foster 2009 'The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change - a case study in Mozambique', Global Environmental Change, 19: 74-88.

Hunt, R.C., 1989 'Appropriate social organization? Water user associations in bureaucratic canal irrigation systems', Human Organization, No. 48.

Intergovernmental Panel on Climate Change., 2001 Climate change: impacts, adaptation and vulnerability Third Assessment Report of Intergovernmental Panel on Climate Change Cambridge: Cambridge University Press.

Kundzewicz Z W and Doll P 2007 'Will groundwater ease freshwater stress under climate change?' Int. Conf. on Groundwater and Climate in Africa (Kampala, June 2008)

Milly P C D, Betancourt J, Falkenmark M, Hirsch R M, Kundzewicz Z W, Lettenmaier D P and Stouffer R J 2008 'Stationarity is dead: wither water management?' Science 319: 573-4.

Molden, D., Frenken, K., Barker, R., de Fraiture, C., Mati, B., Svendsen, M., Sadoff, C. and Finlayson, C.M., 2007: Trends in water and agricultural development. In: Molden, D. (ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture. Earthscan, London, and International Water Management Institute, Colombo.

Molden, D., R. Sakthivadivel, C.J. Perry, C. De Fraiture and W.H. Kloezen.1998. Indicators for comparing performance of irrigated agricultural systems, IWMI Research Report 20, Colombo: International Water Management Institute

Molden, D; J. Lautze, J.; T Shah; M. Giordano; L. Sanford. 2010. 'Governing to grow enough food without enough water: second best solutions show they way', International Journal of Water Resources Development, 26(2):249-263

Mukherji, A., B. Fuleki, T. Shah, D. Suhardiman, M. Giordano and P.Weligamage. 2009. Irrigation reforms in Asia: A review of 108 cases of irrigation management transfer. Background paper # 3. Submitted to Asian Development Bank.

Reid S. and B. Smit, W. Caldwell and S. Belliveau, 2007, 'Vulnerability and adaptation to climate risks in Ontario agriculture', Mitig Adapt Strat Glob Change, 12 : 609-637.

Shah,T.2008. Taming the Anarchy: Groundwater Governance in South Asia, Washington D.C.: The RFF Press.

Singh P and Arora M. 2007 'Water resources potential of Himalayas and possible impact of climate', Jalvigyan Sameeksha 22: 109-32.

Stringer L.C., J.C. Dyer, M.S. Reed and A.J. Dougill 2009 'Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa', Environmental Science & Policy, 12: 748-765.

Suhardiman, D. 2008 'Bureaucratic Designs: The Paradox in Irrigation Management Transfer Policy in Indonesia', Wageningen University, the Netherlands, PhD thesis.

Unnikrishnan A S and Shankar D 2007 'Are sea levels trends along the North Indian ocean coasts consistent with global estimates?', Glob. Planet. Change 57: 301-322.

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