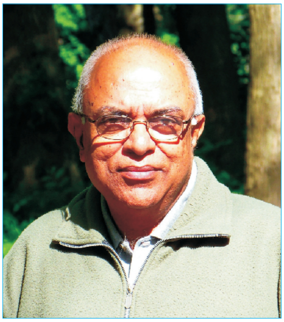
Pt. Govind Ballabh Pant

Memorial Lecture: XIX

PROF. JAYANTA BANDYOPADHYAY

September 10, 2013
at
Kosi-Katarmal, Almora

G.B. Pant Institute of Himalayan Environment & Development
(An Autonomous Institute of Ministry of Environment and Forests, Govt. of India)
Kosi-Katarmal, Almora - 263 643, Uttarakhand, India



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Prof. Bandyopadhyay holds Doctor of Philosophy and Master of Technology degrees in Engineering, both from the Indian Institute of Technology, Kanpur. Earlier, he obtained Bachelor of Engineering degree from Calcutta University, Calcutta in 1966. With his grounding in engineering, after obtaining his Ph. D., he shifted his academic interests to the inter-disciplinary area of Science and Public Interest Research. He is widely recognized as the person who single-handedly drafted the Chapter in Agenda-21 on the World's Mountain for the Rio Earth Summit in 1992. He has a vast working experience and served in different Institutes of repute both in India and abroad. He has been a Visiting Post Doctoral Fellow (1977) at the MIT Centre for International Studies, Cambridge, USA; Assistant Professor (1978-1987) at IIM, Bangalore; Senior Professional Staff (1987-1992) at ICIMOD, Kathmandu, Nepal; Visiting Professor/Director of Research (1993-1996) at the International Academy of Environment (IAE), Geneva, Switzerland; and, Visiting Fellow (1997) at the Institute for Communication and Analysis of Science & Technology (ICAST), Geneva. He is the Founder-President of the South Asian Consortium for Interdisciplinary Water Studies (SaciWaters).

His work on use of Eucalyptus in social forestry, on the impacts of limestone quarrying in the Doon Valley, on the benefits and costs of large dams on the Himalayan rivers, policy for sustainable development of the Ganges-Brahmaputra-Meghna basin, etc. are cited globally. His book Water, Ecosystems and Society published by Sage is a landmark publication on the subject of water systems tudies in South Asia.

Prior to his superannuation in December 2012, he served as Professor & Head (since1997) at the Centre for Development and Environment Policy,Indian Institute of Management, Calcutta.

Prof. Bandyopadhyay has several honours to his credit. He is a Fellow of the India-China Institute, The New School, New York, USA; invited member of the UNESCO Expert group to address the Future of Planet Earth; EU Erasmus Mundus Visiting Professor (2010-12) to the School of Environment &

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Sustaining the Himalaya as the Water Tower of Asia

Need for Innovative Policy Making from India & China

Jayanta Bandyopadhyay

19th Pt. Govind Ballabh Pant Memorial Lecture
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G.B. Pant Institute of Himalayan Environment & Development
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It is indeed a privilege and honour for me to be here at the Govind Ballabh Pant Institute of Himalayan Environment and Development to deliver the 19th Pandit Govind Ballabh Pant Memorial Lecture. Late Shri Govind Ballabh Pant ji was an important activist in the independence movement of India and a leader of profound popularity. On many important issues Pant ji successfully put forward the interest of the people of the Himalaya while leading the struggle against the British rulers or in the government of the State of the then Uttar Pradesh in independent India. Today, the task of extending his spirit of advancing the cause of the mountain areas throughout the length of the Indian Himalayan Region is being promoted by this Institute that carries his name. As a lifelong student of environment and development in the Himalaya, I pay my humble respect and homage to Pandit Govind Ballabh Pant ji, on the occasion of his 126th 'Birth anniversary'.

1. Background

The crucial role of the mountains of the world as the creator and provider of very large volumes of freshwater, and as the natural site for the storage of this vital service of natural ecosystems drew the special attention of the leaders of the world during the Rio Earth Summit in 1992. In Chapter-13[1] of Agenda-21 that was approved at the Rio Summit,

[1] *In the preparatory stages of the Rio Earth Summit, there was no plan for including a Chapter in Agenda-21 outlining the environmental action needed for the mountains of the world. A group of mountain scholars, including the present author, appealed for the inclusion of a Chapter on the mountains. After several rounds of discussions, the Secretariat of the Rio Earth Summit accepted the request. The present author was invited to draft the text of such a Chapter. The draft submitted was later approved in the 1992 Summit Conference.*

this global importance of the mountains as providers of freshwater was specially stressed as one of the main reasons for focusing attention of the global community to the mountains and uplands.[2] The mountains and uplands soon started to be described as the water towers for the world that make vital contributions of freshwater supply to human societies and economies (Bandyopadhyay, 1996). The FAO (2011) has pointed out that the mountains and uplands provide freshwater to at least half of the global human population, for domestic uses, irrigation, industry and energy production. Accordingly, to support survival of all forms of life and provide the basis for continued human well being in the future, the mountain environments also need to be sustained as efficiently functioning ecosystems.

For Asia, this crucial role of water tower is played by the mountain Himalaya. While the largest share of the terrestrial area of the Himalaya lies within the boundary of China, probably the largest share of water flowing in the rivers emanating from the Himalaya passes through India. This makes China and India the two most important stakeholders for sustaining the Himalayan water tower. In the past centuries both countries have depended very heavily on the water flowing in the Himalayan rivers and there is every indication that this dependence will not only continue but get larger in the future centuries. In terms of the number of people who are vitally dependent for their survival and wellbeing on the provisioning of water, the Himalaya comes first among all the mountains of the world. The Himalayan region (Bandyopadhyay et al., 1992 modified later), encompassing the Hindu Kush mountains and the Tibet Autonomous Region of China, spans an area of more than 3.44 million square kilometers spread over Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan (Figure 1). The added significance of the Himalaya as the water tower of Asia comes from the fact that the region stores more snow and ice than anywhere else in the world, outside the two poles. Hence it is also getting popularly described as 'The Third Pole' of the world.

The Himalayan region contains the highest mountains of the world and the interaction of the orography of the Himalayan landmass with the Indian summer monsoon and the East Asian monsoon generates large amounts of precipitation. The monsoon dominated climate brings much of the annual precipitation during the months of May to September. Ten major rivers of the world drain the Himalayan region, making it a crucial ecological entity over a large geographical area of

[2] *The mountains are distinguished from the uplands by a dividing line of altitude, which is 1000 m asl. However, many areas that are not characterized as mountains according to this divide perform hydrological roles as good as the mountains. In this paper both mountains and uplands will be described by the single word 'mountains'.*

Asia. Some of these rivers include the Huanghe and Yangtze, emerging from the Chinghai plateau providing water to the densely populated parts of north-eastern China; Mekong, Salween and Irrawaddi, flowing southwards from eastern Tibet into S-E Asia; the Ganges-Brahmaputra-Meghna, draining large areas in both the north and south aspects of the Himalaya providing about two-thirds of the total annual river flows for India; and the Indus, the lifeline of Pakistan (Figure 1).

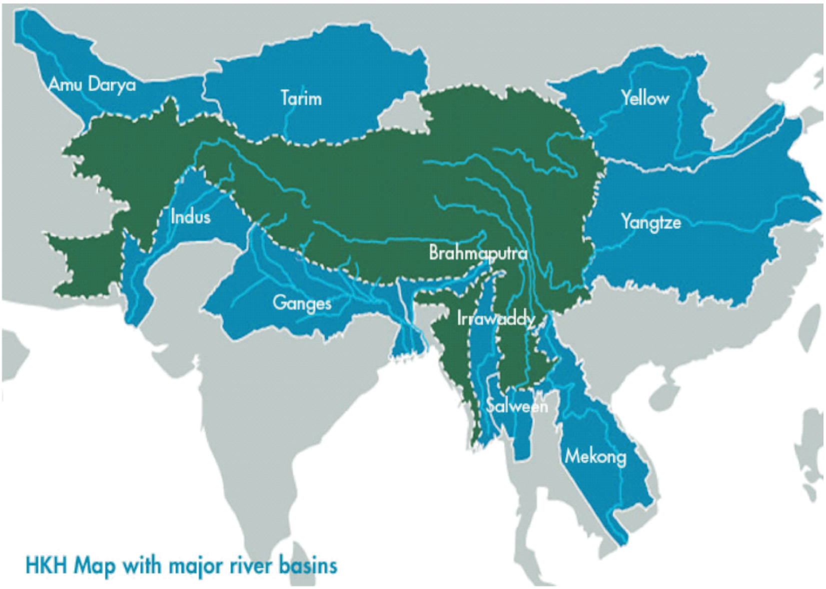

Figure 1: The Himalayan region (green) with basins (blue) of the Himalayan rivers (available at http://www.icimod.org/index.php?page=43).

The rainfall is especially high along the foothills of the southern aspect of the Himalaya and the south-eastern parts of the Chinghai-Tibet region. The Himalayan rivers have supported the growth of several great civilizations of Asia, like in the basins of Huanghe, Yangtze, Indus, Ganges, Mekong, etc. As a mark of their crucial dependence on waters from Himalayan rivers, people in China and India have named the Huanghe and the Ganges respectively as their mother-river. Without the existence of the Himalayan water tower, these civilizations would not have flourished and human history and geo-politics in Asia would have taken very different routes. The basins of the Himalayan rivers are the home of about 1.35 billion people (Lamadrid and MacClune, 2010). However, more than 3 billion people benefit from the water supplies as well as the food and energy produced with water from these river basins (http://www.icimod.org/ ?q=3487).

The Himalayan rivers have been used by the humans for millennia but only recently the quantification of the total water produced by this mountain is being undertaken. Bookhagen and Burbank (2010) have provided a hydrological budget and offer important correlation between precipitation and run-off in 27 Himalayan rivers in the Southern aspect, starting from the Yarlung Tsangpo in the east to the Indus in the west. The flows in the rivers are constituted by rainfall as well as snow and glacier-melt. From the east to the west, the relative contributions of these inputs vary significantly. For example, Yarlung Tsangpo in the eastern part receives about 34% of its flow from snow and glacier-melt, while the same contribution for Indus in the west is higher, almost double at 66% (Bookhagen and Burbank, 2010). Other rivers in between these two limits show an almost continuous trend ranging between these two values.

A very important distinguishing feature of the Himalayan rivers is that, not only do they carry large volumes of water, their flows also embody great amounts of sediment and energy, both potential and kinetic. The ecology of the interaction of these three constituents of the flow of Himalayan rivers is extremely important but complex. The sediment generated in the Himalaya gets transported all the way to the Bay of Bengal, contributing to the southwards advance of the Bengal Deep Sea Fan which extends up to the Equator (Curray and Moore, 1971). There is, unfortunately, a great knowledge gap in the scientific description and quantification of the totality of the ecological processes involved in the flows of the Himalayan rivers and interaction of the water-sediment-energy system in the various parts of their basins. A lot of research on ecology and geo-morphology of the Himalayan rivers as well as the ecosystem services provided by them is urgently needed to be undertaken. In the absence of a comprehensive ecological knowledge base, human interventions in the Himalayan rivers will remain tied with a rather reductionist disciplinary knowledge base. This will keep human interventions sub-optimal and subject to tremendous risks and uncertainties. In recent years another major concern has emerged in relation to human dependence on the Himalayan rivers. The urgency associated with that dependence becomes clear when the potential impacts of global warming and climate change on the Himalayan rivers are considered.

"Mountain systems are particularly sensitive to climate change.... The rate of warming in the Third Pole region is significantly higher than the global average, and the rate is higher at higher altitude, suggesting a greater vulnerability of the cryosphere environment to climate change.

This trend is expected to continue. Climate change projections suggest that all areas of South Asia are likely to warm by at least 1°C by the end of the century, while in some areas the warming could be as high as 3.5-4°C. The life and livelihoods of the people in the Third Pole region is challenged due to climate change, and the stability and prosperity of the region affected by the Third Pole is at risk, which will have implications for all of Asia and for the world" (http://www.icimod.org/?q=3487).

In order to get clearer predictions on flows in the Himalayan rivers, what is needed is the development of Himalaya specific climate models. The climate process in the Himalaya is itself not well known and changes in the climate parameters caused by projected rates of global warming are even more difficult to obtain. In two recent publications by Immerzeel et al. (2010, 2013) this problem of the non-availability of a climate model appropriate for the Himalaya emerges clearly. He reported quite different results on the Himalayan rivers in these publications. Nevertheless, in 2013 the authors have made the prediction that till about the middle of the present century there will not be a serious decline in the snow and glacier melt flows in the Himalayan rivers. Further, such river basins would be able to sustain the increasing water demands in their basins. However, thereafter, there would be a decline in the snow and glacier melt component in the flows while the rainfall component will become larger. Thus, global warming and climate change have made it almost mandatory for Asian people to better understand the eco-hydrology of water from the Himalaya and adopt more comprehensive policies to sustain it as the water tower.

It is also important to remember that while Himalayan waters have played a great role in the establishment of great civilizations in Asia, these rivers can also cause immense damage when hydro-meteorological extreme events occur. Such damages can greatly multiply when human interventions are made without due ecological knowledge of the Himalayan environment. The heavy rainfall and floods in some parts of the State of Uttarakhand is such a case in point (Bandyopadhyay, 2013a).

2. Himalayan Water Tower and Global Economic Leadership of Asia

Focus on improving the quality of life of the people through agricultural and industrial growth was omnipresent in the policies of independent India which came into existence in 1947 and the People's Republic of China, which was established in 1949. However, the nature and extent of their economic growth have been far wider and greater in the past few decades. Srinivasan (2006), Yusuf and Nabeshima (2010) and Palit (2012), among several others, have analyzed this phase of economic growth in these two countries with special reference to their emerging leadership roles in the international trade and economy. Shambaugh (2013) has presented the emergence of modern China as an important player in the global economic, cultural and diplomatic arena. Western media is on a constant lookout for articles that document the environmental impacts of these emerging leaders of the global economy. From this point of view, understanding of China is in a very embryonic state in India. It is indeed important for us in India to get a clearer and wider understanding of our neighbour, which, in a few years time, will become the largest economy of the world. The economic future of this part of the Kumaon region we are in, can transform dramatically with full and functional reopening of the China-India trade.

In the recent decades, these two countries most dependent on the Himalayan rivers, as well as the two most populated countries of the world, have recorded annual GDP growth rates of 8 to 10%. By 2028 the population of India is expected to cross the 1.4 billion mark, surpassing that of China, which has attained since 2012 a phase of decline in population (Figure 2). In addition, future trends projected for their economies indicate that the GDP of China, with about USD 6000 billion in 2010, and India, with about USD 2000 billion on the same year, are expected to grow larger by 2025 by a factor of 2.5 to 3.0 (Figure 3).

Rapid economic growth results in new demographic pictures and consumption patterns. It is projected that by 2035, 70% of the population in China will live in urban areas while in the case of India the percentage of urban population will be about 40 by 2026. Hence, in preparation of sustaining their rapid economic growth process and betterment of the quality of life of their large populations, both China and India will have to take very informed and wise measures to make adequate amounts of water available for domestic uses, natural ecosystem processes and diverse economic activities. In the case of both China and India, a new dependence on the Himalayan rivers has emerged as hydro-power generation. In the business-as-usual (BAU) scenario for China, the present annual availability of 873 BCM will face a total requirement of 1138 BCM by 2025. Addressing this challenge needs some drastic policy innovations. Similarly, in the case of business-as-usual in India, the total utilizable water of 1123 BCM is put against a projected water demand of 1093 BCM (estimate by the Standing Sub-Committee of the MoWR) by 2025. Using a conservative assessment by Amarasinghe et al. (2007) puts India's total water requirement at 900 BCM by 2050 with several institutional changes built in. Hence, in the case of India, water requirements in the BAU path would catch-up with the amount of utilizable water in the second half of the 21st century.

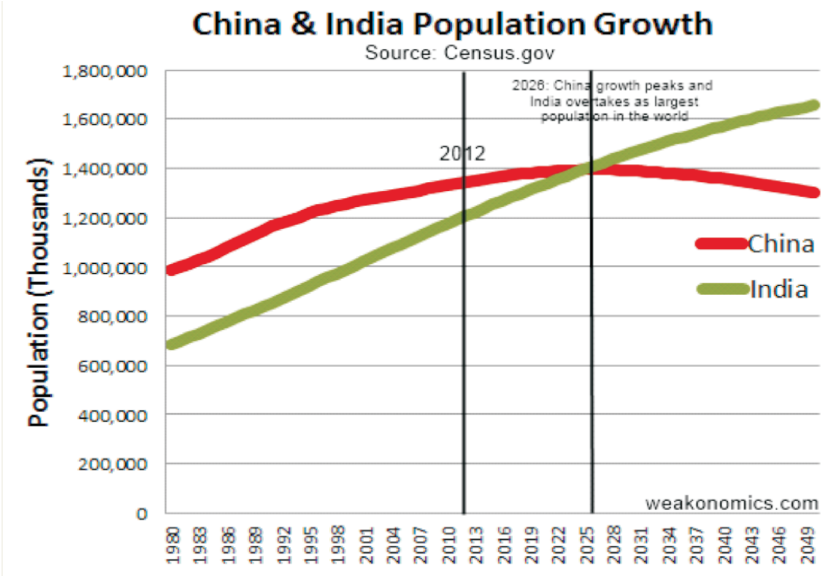

Figure 2: Population of China and India till 2050.

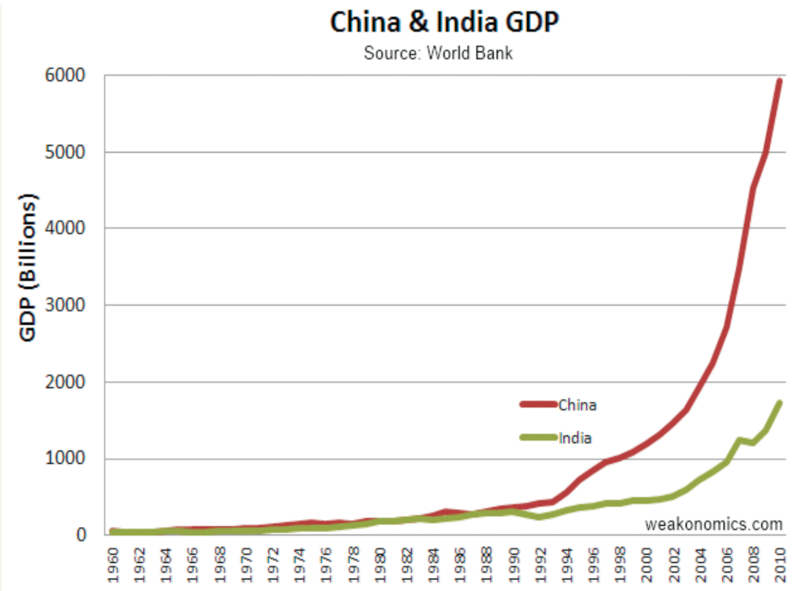

Figure 3: Growth of GDP of China and India till 2010.

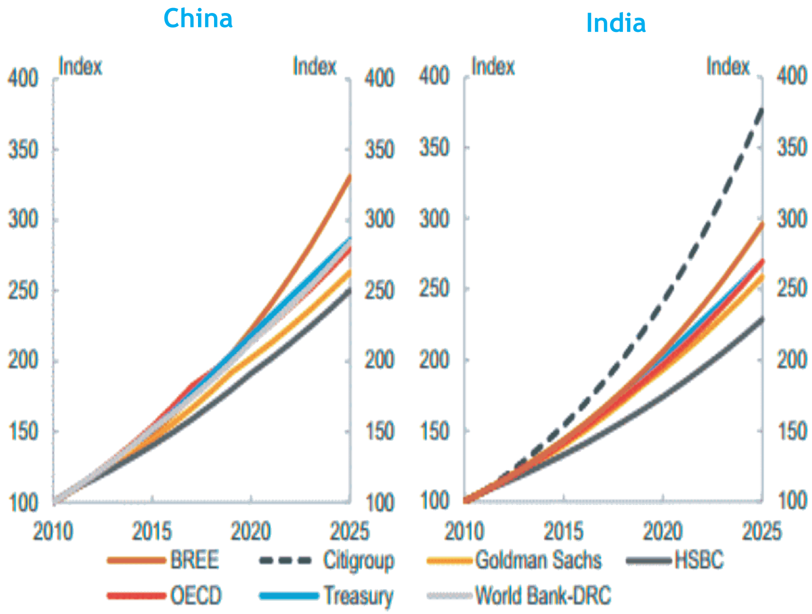

Figure 4: Projected growth of GDP of China and India during 2010 – 2025.

In this context, in both countries the Himalayan rivers have been the main sources of water and are also seen as the best options for providing water security in the future years. Whatever be the imperative, the largest economy of the world and the largest populated country of the world would seek greater supplies of Himalayan waters for their people and economies. In addition, since these rivers are now increasingly seen as provider of hydro-electricity, reducing the dependence of China and India on fossil fuel for energy generation, several observers in the international media have already taken a view of ecological doomsday for the Himalaya from dam construction (see for example a recent sensational article by Vidal in The Observer, 10 August 2013). Such journalistic writings on the dams in the Himalaya give a special status to the Himalayan rivers as contributors to the global economy. In China the Yangtze is already being used to augment water supply in the drier and densely populated northern plains through the South to North water transfers, while in India both the Ganges and the Brahmaputra have been identified in governmental strategy of interlinking of rivers, as the provider of water for increased supply to the drier areas of the country. However, such projects at present are driven by traditional water engineering and supply side solutions. They have been facing disagreements at the provincial levels and environmental criticism (Berkoff, 2003; Prabhu, 2012; Bandyopadhyay and Perveen, 2008). The fact that by 2050 China and India will have about 3 billion people between themselves, and both together will hold a very large share of the global economy, in the coming decades Himalayan water tower will become a key water source for the global economy. Hence, futuristic and informed measures for sustaining the Himalayan rivers will become significant. The present situation poses a challenge to research and policy making for the Himalayan rivers on a totally different direction and scale. In particular, such a new phase would need a paradigm shift in the way economic development in the Himalaya has been seen so far. One significant change will involve the way it may be necessary to look at water as a prime product of the Himalayan landmass, and not as a factor input to the presently accepted prime products like crops, fruits, flowers and vegetables. This opens up a great research agenda for professionals and institutions working on strategy for sustaining the Himalaya.

3. A New Policy Framework for Sustaining Himalayan Rivers: Role of India and China

It has been mentioned earlier that in both China and India the perennial nature of flow in the Himalayan rivers helped sustain the growth of food production and support large populations. More recently waters of Himalayan rivers have extended important support to the process of rapid industrialization and continued urbanization in both countries. However, as was the case with the industrially advanced countries in the past 150 years or so, and particularly in the aftermath of the Second World War, rapid and widespread exhaustion and degradation of natural ecosystems have also been the result in China and India. In this backdrop, with the destabilization of the water systems, availability of water would impose restrictions on the growth process. As has been asserted by the Strategic Foresight Group (2011), "both India and China will face a drop in the yield of wheat and rice anywhere between 30-50% by 2050".

Among all the countries sharing the Himalayan rivers it is China and India who have the greater stake in sustaining the rivers of this mountain. In the case of China, the growth in the total throughput of the economy will put immense pressure for the augmentation of available water supplies. Even if the economy of China grows annually at the moderate rate of 6 or 7% over the second decade of the 21st century, it is expected to become the country with the largest economy in the world. The total water requirement for the Chinese economy by 2050 will be about 2 times the total utilizable amount of 873 BCM as per the business as usual path.

Similarly, as India becomes the largest populated country in the world, provisioning of water for food security and human settlements will become a very big challenge. Moreover, industrialization and urbanization in India in the coming decades would exert a not very insignificant pressure on the available volumes of water. Conflicts over water, whether among sectors or regions have already become quite extensive in India (Cullet et al., 2012). Hence, whatever be the nature of the compulsion, there will be a steep rise in the demand of water for supplies and energy production in future decades.

The importance of these two countries in the projections of global water supply and demand has been clearly established in a study by Amarasinghe et al. (2008). They pointed out that China and India, "constituting more than one-third of the world's population, are the two most populous countries in the world. And, by the middle of this century they need to feed 700 million more people. Second, both countries have huge economies. Their economic growth in the recent decades—since the 1970s in China and since the 1980s in India—has been remarkable. With booming economies, people's expenditure patterns are changing and so do their lifestyles. Rapid urbanization is also adding fuel to these changes". A correlation of the changing lifestyle and the new consumption patterns for a large part of the population in China and India has been made by Hubacek et al. (2007). In addressing the future challenges, both countries have made plans for augmentation of water supplies. To provide more water to the densely populated and water scarce north China plains, China has started to transfer water from the Himalayan river Yangtse by the South to North Water Transfer project. Similarly, much of India's future water augmentation plans depend on linking the Himalayan tributaries of the Ganges and Brahmaputra to other river basins that are less water endowed. How are China and India addressing these growing challenges in their water security, is being watched with utmost attention, especially from the industrially advanced countries (see for example www.circle ofblue.org/waternews; Vidal, 2013).

The environmental degradation in China during the period of leadership by Chairman Mao is recorded in details by Shapiro (2001) in her book "Mao's War on Nature". The environmental problems of the rapid economic growth during the post-Mao period of opening up and economic liberalization from 1978 onwards has been described well by Economy (2010) in her book "The River Runs Black". These books and numerous other reports indicate the seriousness of the fallouts of China's miracle economic growth on its rivers. In the case of India, in the years immediately after planned development was initiated, the structural interventions into the Himalayan rivers were quite large. The downstream changes in the river flows and the quality of water was accepted as a cost that need to be paid for providing better quality of life to the people in independent India. However, as in the case of China, in India also the cumulative impacts of economic activities drew governmental attention largely after the 1972 Stockholm Conference. Bandyopadhyay et al. (1984) in their book "India's Environment: Crises and Responses" have given an early alarm on the growing challenges faced by the India's natural environment. However, in spite of such early observations, as noted recently by the World Bank's senior environmental economist Muthukumara Mani (2013), "India has performed remarkably economically, but that's not reflected in its environmental outcomes. 'Grow now, clean up later' really doesn't work".

If the Himalaya needs to be sustained as the water tower of Asia, China and India will be the largest stakeholders in that process. In their own national interests, as well as in the broader interest of the Himalayan region, it will be an imperative that policy measures based on comprehensive and inter-disciplinary knowledge base are innovated and applied on the Himalayan rivers as soon as possible. Whatever the compulsion, both China and India will have to innovate their ways for designing a new policy framework for their Himalayan rivers. A large part of this innovation would be country specific but on many areas, especially for the trans-boundary rivers, mutual learning and cooperation will be beneficial and economical for both countries (Bandyopadhyay, 2013b). In this background, it may be appropriate to look at the present framework for water policy and laws in both the countries.

3.1 Present Water Policy of China and the Himalayan Rivers

Research on and documentation of the ecological status and environmental degradation of Himalayan rivers and future policy options is an important area of research work in most Universities in China and the various Institutes of the Chinese Academy of Sciences. Governmental policy emerges after interaction with the academic community, a process in which opinion of the University faculty members and researchers in the Academy have often not been consistent with governmental position. The Three Gorges dam on river Yangtze is an important case in point on this aspect. A book entitled "Resource-oriented Water Management: Towards Harmonious Coexistence between Man and Nature" and written by Wang Shucheng (2002), a former and influential Minister of Water Resources in China, makes it apparent that internalization of social and ecological dimensions in policy is a matter of time. A scientific and technological roadmap to 2050 for water in China has recently been prepared by the Academy (Liu et al., 2012). According to this roadmap, China's "industrial water recycling rate and the utilization efficiency of agricultural irrigation water will be 50% and 65% in around 2020; 65% and 75% in around 2030; and 85% and 85% in around 2050". Rivers in China are managed by river basin Commissions which work from within the Ministry of Water Resources of China. The provinces sharing a river basin function within a framework and water allocation provided by the basin Commission. For the rivers of China, the main environmental challenges that have been identified are related to: (a) water scarcity, (b) floods, c) pollution, and (d) degradation of the ecological status of the rivers. Impacts of global climate change on the rivers and related adaptation mechanisms are integral to all area of research on the Himalayan rivers.

While lean flows and floods are unavoidable features of a monsoon dominated river system, the degradation of the ecological status of the natural ecosystems have been the result of extensive transfer of water with traditional and supply oriented water engineering interventions. The drying up of China's mother river, Huanghe during part of every year for about 3 decades drew extensive environmental criticism from both inside China and outside (see Zusman, 2000). In both summer periods of 1997 and 1998, the Huanghe failed to reach its mouth at Bohai Bay for 226 days. In the spirit of a responsible scientific community, scientists in China tried to convert the problems into opportunities for institutional innovations. A paper by Xia and Chen (2001) in Hydrological Sciences Journal provides a detailed framework for policy for China's rivers, in particular with respect to the rehabilitation of their ecological status. Scientific updating of the governmental policy with respect to sustaining the ecological status of the rivers in China became apparent when the State Council in December 2010 adopted the Document No. 1 on conservation and development water, giving it the highest priority in policy. The environmental sustainability of two most used Himalayan rivers within the boundary of China, Huanghe and Yangtze will get a big push from this policy.

The basic strategy of China in respect of water is shown in Figure 5 below, which is prepared by the HSBC on the basis of the Document No. 1. It is projected that the total water withdrawal of China will flatten at around 700 BCM by 2030, against a potential utilizable amount of 873 BCM. A broad review of research publications indicate that important progress has been achieved in science and technology for the Himalayan rivers in China. In this paper it is not possible to go into the details and mention will be made of the specific areas. Addressing the age old problem of floods and water scarcity in the Himalayan rivers remain important and central. The closely related question of sedimentation and its role in the operation of storage structures constitutes another important focal point of research. The evolution of the design of the Xiaollangdi dam on the Huanghe after the relatively unsatisfactory performance of the Sanmenxia dam in addressing the very high sediment loads, is such a case in point (Wang et al., 2007).

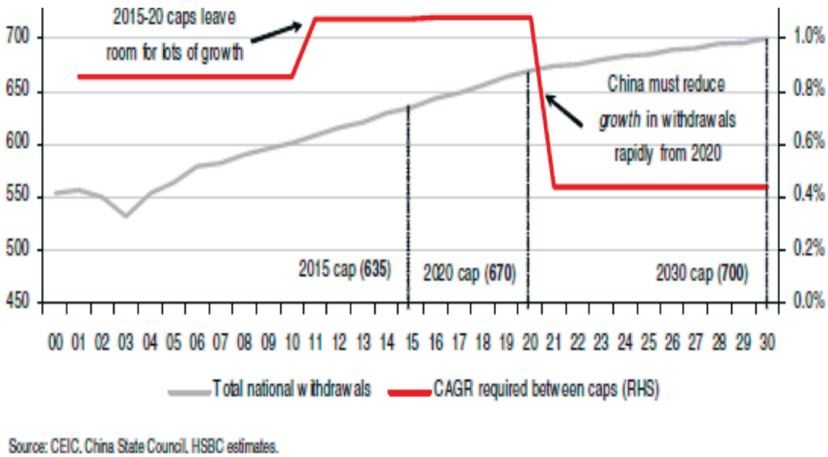

Figure 5: China's planned total withdrawals and caps till 2030 in BCM.

The most significant research is probably going on the relations between flow allocation for ecosystem functioning and services, including the flow needed for the flushing of sediment beyond the coastal areas. The Huanghe being the river most degraded ecologically, and also the river with a very high sediment load, has attracted the attention of many researchers internationally. Baosheng et al. (2004) have provided an innovative management strategy for the Huanghe. The work of Jiang et al. (2010) exemplifies the interest that the scientific community has taken on the assessment of ecosystem based water requirements in the Huanghe. The impacts of global warming and climate change on stream flow in the upper catchment areas has attracted significant attention in China and research on topics ranging from downscaling of regional climate models to adaptation of projected changes in stream flows are in quite an advanced stage (UNESCO, 2010). On the whole, it appears that the policy makers in China have at last woken up to the need for ecological sustainability as the prime mover of policy than supply maximization. Future attention to the Himalayan rivers in China will be directed towards reduced extraction from the mountain areas of the basin and clear recognition of the need for ecological rehabilitation of all parts of the rivers. From this point of view, in addition to storage for supplies, the role of dams will increasingly evolve with time, as floods created to carry the sediments out to the confluence with the oceans and beyond gains importance.

There is one significant policy matter that can cause serious conflicts. That is the demand of the larger national economies on the Himalayan waters and the status of local needs and access. This matter can be sorted out under agreements like the payment for ecosystem services. This is a very important policy innovation that is essential to articulate clearly.

3.2 Present Water Policy of India and the Himalayan Rivers

The Draft National Water Policy of India (2012) is the most recent document and takes the view that "the availability of water is limited but the demand of water is increasing rapidly due to growing population, rapid urbanization, rapid industrialization and economic development. Therefore, availability of water for utilization needs to be augmented to meet increasing demands of water". Any increase in supply would mainly have to be made available from the Himalayan rivers of Ganges and Brahmaputra (Salehim et al., 2011). Out of the annual average surface water potential of 1869 BCM for India, about 1184 BCM are flowing in the Himalayan rivers (Gaur and Amarasinghe, 2011), which establishes their future potential.

An alternate assessment of annual water availability in India has been made by Chaturvedi (2001) who presents a total availability figure of 1276.5 BCM of which 630.4 BCM is shown as available from the Himalayan rivers. Research on Himalayan waters in India is characterized by a distributed attention to the various spatial scales of use of water. Publications have been made on topics ranging from the micro-level availability and use of water in micro-watersheds to the spatial levels of large river basins (see Tambe et al., 2012; Blackmore, 2006). The Draft National Water Policy of 2012 has not made policy guidelines specific to the Himalayan rivers, probably all these rivers are categorized as 'international'. Even when the infrastructure in the water sector is analyzed, the ecological perspective is very much absent while traditional economic analyses form the core of related outputs (see for example Gulati, 2011)

Nevertheless, water in the Himalayan rivers will be central to any strategy for future water security of India. These rivers need to be addressed with updated knowledge and clear priorities. Here is a problem that needs early solution. Both the ecological and hydro-meteorological research on the Himalayan rivers in India have confidentiality attached to them, which acts as an obstacle to the growth of a Himalaya specific water science. The corrective inputs to policy on the Himalayan rivers in India have been few. Some of the independent professionals have made informed criticisms of the traditional concepts used in policy making in India and offered an alternate framework (Iyer, 2011). More frequently the communities affected by governmental projects and some non-governmental organizations (NGOs) have taken positions opposing the governmental approach. However, many NGOs advocate a policy of total non-intervention in the Himalayan rivers, especially the Himalayan parts of the Ganges. There is, at present a very large dam building activity in the Himalayan rivers of India which is foreclosing the space for a more ecologically informed and socially inclusive policy for these rivers. In order to arrive at such a policy framework for the Himalayan rivers in India, areas on which innovation in research and policy is needed, includes:

1) Filling-up of gaps in hydro-meteorological database keeping as reference the WMO recommended standards for spatial density of observatories mountains.

2) Priority to research on generation of interdisciplinary knowledge of the ecological processes and ecosystem services of the Himalayan rivers, including those related to monsoon high flows. The interactive processes connecting water, sediment and energy is an important part in such initiatives.

3) Development and application of downscaled climate models that is appropriate for the Himalaya.

4) Innovating river engineering with the objective of sustaining the ecological processes and ecosystem services of the Himalayan rivers, thus generating a new approach to structural interventions into these rivers.

4. Sustaining the Himalayan Water Tower: Areas of Innovations in Science and Policy

In just a few more years China may become the country with the largest economy and India may become the country with the largest population in the world. Their joint requirement of water will be a large part of the total global requirements. In order to keep up the well being of their own people, China and India in particular, and countries depending on the Himalayan rivers in general, the Himalayan ecosystems need to be sustained as efficiently functioning ones, delivering the expected ecosystem services. In the context of the recent results of climate modeling, the good news is that more water will be precipitated as rainfall. The difficult part is that as the 21st Century progresses, the snow and glacier melt part of the flows could decline. This poses a challenge to policy making for Himalayan rivers that is backed by ecologically informed river engineering. The two large Asian countries are the biggest beneficiaries of the Himalayan waters. With good scientific and technological competence in the various academies and institutions in these countries, addressing this task of generating a Himalaya specific water science and policy would not be an impossible task, for them individually, and in collaboration, wherever needed. Special attention needs to be focused on the specifics around the following:

i) Assessment of average annual water production in these rivers including contributions of snow and glacier melts in them.

ii) Strategic environmental assessment for engineering interventions and complete transparency of the project details.

iii) Development of Himalaya specific climate models for the understanding of impacts of global warming and climate change on future water endowment of these rivers.

iv) Development of a sediment policy for each major river and related engineering design for sediment flows and deposition along predicted locations in all parts of the basin.

v) Understanding of the ecological contributions of water flows (named here as 'Environmental Flows' in the absence of a better scientific name).

vi) Recognition of water as a main product of the Himalayan landmass and restructuring of land use policy from this perspective. Designing of new institutional arrangement for policy making on river basins with ability to take decisions on inter-State issues, prescribe target efficiency of water use, etc.

vii) Arrive at new mountain-plains institutional mechanisms to recognize water flow as a contribution of the Himalayan region to the rest of the river basins areas, and consequent mechanisms for meeting costs of maintaining such flows, based on the principle of payment for ecosystem services.

I end this lecture with the observation that we have taken the Himalaya for granted over centuries. With the present pressure on the natural resources of the Himalaya, time has come for us to try to understand the Himalaya at a deeper level today, so that another 50 or 100 years into the future, we can gladly say that our timely interventions have kept our Himalayan water tower as good as ever.

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Prof. Bandyopadhyay has written over 10 books/ monographs, 25 chapters in books and 50 research/policy papers in journals in different disciplines, focusing on Mountain ecosystems, water resource management, sustainable development, climate change, global environment planning and diplomacy, etc. He has traveled worldwide and delivered over 100 invited lectures. Besides, he is an active member and associated with several professional bodies/societies.

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