ECOLOGY

China, India, and the Environment

Cooperation between China and India can curtail biodiversity loss, mitigate climate change, and reduce deforestation.

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China and India, the emerging economic giants of the world, will play a significant, perhaps a dominant, role in shaping the environmental outcomes for our planet in the 21st century. Both countries are expected to maintain an 8 to 9% rate of economic growth over the next several years (*1*). Even when much of the world is experiencing a recession, China and India in 2009 are projected to achieve high Gross Domestic Product growth (China, 8.4%; India, 6.2%; world, –2.2%) (*1*). Development in China and India is fueled not only by the natural capital within the countries, but also increasingly by imports of raw materials, particularly from southeast Asia. Both nations import ~9 million tons of crude palm oil annually—almost one-quarter of global production—mostly from Malaysia and Indonesia (*2*). The degree to which China and India consume natural resources within their boundaries, and beyond, will largely determine future environmental, social, and economic outcomes. The two countries have been engaged in a border dispute that included a bitter, but brief, war in 1962. We propose that much more earnest cooperation between the world's two most populous countries will be vital for mitigating biodiversity loss, global warming, and deforestation.

CREDIT: KAMALJIT S. BAWA

A Himalayan landscape—linking environmental integrity with peace and security.

Biodiversity, Water, Climate, and Forests

Nowhere are these issues better exemplified than in the Himalayas, the 2400-km-long chain of mountain ranges stretching between the Indus and the Brahmaputra River valleys (see the picture, above). The unique biodiversity of this region faces multiple pressures, including those associated with the military presence of both countries along the international border (*3*). This situation is particularly damaging to fragile subalpine and alpine ecosystems, which recover slowly from disturbance. Furthermore, resources are so scarce in these cold, high-altitude areas that the armies often use rare species for fuel.

Both countries are already facing severe surface and groundwater shortages (*4*, *5*). Given the increased snow and glacier melt in the Himalaya–Hindu Kush region (*6*), the hydrology of major Asian rivers will be severely affected in the near future. The rush to harness hydroelectric power by building hundreds of dams on both sides of the earthquake-prone Himalayas will further accelerate changes in hydrology and the effects of climate change. For instance, India plans to increase hydropower projects in the Himalayas from 74 to 355 over the next 15 years, increasing the capacity from 15,208 to 126,588 MW (*7*); China is planning 750 projects in Tibet alone (*8*). Further, China may also divert water from the Tsangpo-Brahmaputra, one of the largest rivers in Asia, before it enters India (*9*). If true, dispute over political boundaries could extend to water resources.

Exploitation of Himalayan resources is likely to be accelerated as energy consumption rises more rapidly in Asia than anywhere else. China and India, respectively, are already the world's top and the fifth-largest emitters of greenhouse gases. Snow melt from Himalayan glaciers constitutes a principal water resource during the summer months for at least half of the world's population (*10*). The synergistic effects of decreasing water resources, loss of biodiversity, increased pollution, and climate change may have negative social and economic consequences and, even worse, escalate conflicts within and between the two countries.

Beyond the Himalayas, both countries are enlarging their ecological footprint in Asia. If current trends continue to 2020 (*2*), China and India may be importing 45.8 and 18.8%, respectively, of their roundwood demand, or 64% of all currently produced roundwood in Asia. These imports will contribute to deforestation-driven greenhouse gas emissions and biodiversity loss in Asia.

Benefits and Barriers to Cooperation

China and India have much to learn from each other. For instance, India's energy efficiency is higher than China's (*11*). However, China has much to offer to India in poverty reduction, health care, and large conservation programs, including the Natural Forest Conservation Program and the Grain-to-Green Program (*12*).

Cooperation between the two countries could help mitigate climate change, environmental damage, and biodiversity loss both regionally and globally. Both countries, but especially China, have experience with microhydropower projects. Local communities, especially in the Himalayas, have a tremendous

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knowledge of biodiversity, hydrology, and climate change (*13*). Sharing this knowledge could enhance the development of appropriate approaches and technologies. Both countries have recently increased forest cover (China, 157.1 million ha in 1990 to 197.3 million ha in 2005; India, 63.9 million ha to 67.7 million ha) (*2*). Sharing expertise in afforestation and in the development of policy frameworks for sustainable use of forest resources with the rest of Asia could contribute to reduction in deforestation and to an Asia-wide effort to mitigate climate change through both the preservation and enhancement of forest carbon stocks. Cooperation between the two countries can also have a huge impact on trade in tiger body parts and on conservation of the last remaining and the largest population of an icon species.

So far, collaboration and coordination between the two countries in dealing with environmental challenges has been limited, although there have been several signed agreements since 1988 (*14*). In 1993, a Sino-India collaboration agreement on the environment was signed (*15*). In the past few years, there have been research collaborations on terrestrial ecosystems, atmosphere-ocean-biosphere interactions, and related modeling (*14*) but the level of overall scientific collaboration has been lower than expected (*16*). In 2009, an international symposium on biodiversity and environmental changes in the Himalayan region was held in China and was attended by Chinese and Indian scientists (*17*). More recently, India and China have signed an agreement to comonitor glaciers (*18*) and to collaborate in the areas of energy, agriculture, and afforestation (*19*).

Despite the presence of these frameworks for cooperation, major barriers to collaboration between China and India persist. Linguistic and cultural differences perhaps tend to keep Indian and Chinese academics apart even in international meetings. Unresolved border disputes also deter cooperation. Furthermore, the severity of environmental challenges, and the opportunities for and benefits of coordinated and collaborative actions remain underappreciated.

Steps Toward Deepening Cooperation

First, both countries need to overcome cultural and linguistic barriers. Although China has been actively promoting Chinese language and culture internationally in recent years, only 2 out of 523 Confucius Institutes that have been established worldwide to support local teaching of Chinese are in India (*20*). Similarly, India needs to promote Chinese studies in India and Indian studies in China.

Second, with sparse or no human populations, some of the disputed areas or the areas where armies have been amassed, which are alpine zones, are ideal for conversion to transboundary protected areas or peace parks, similar to the proposed K-2–Siachen Peace Park between India and Pakistan (*21*). The creation of peace parks—for which the United Nations Educational, Scientific, and Cultural Organization (UNESCO) could develop guidelines—and jointly run research stations could not only protect biodiversity, provide key ecosystem services, help mitigate climate change, and foster scientific collaboration, but also promote cooperative conservation actions and peaceful resolution to the border dispute (*21*).

Third, 2009 marked the 15th anniversary of agreements signed between the Chinese and Indian Academies of Sciences. The academies could exercise strong leadership in highlighting environmental issues, initiating joint actions, and fostering scientific exchanges. The Indian academies are gearing up to be more active in policy-making and could accord high priority to policy-oriented initiatives. Exchange and joint supervision of graduate and postdoctoral students could build on existing programs, such as those run by the Academy of Sciences for the Developing World (*22*). The governments could also establish a joint grants program for Himalayan research, as China and India have taken preliminary steps to establish a framework for scientific cooperation (*23*). The ecological societies of China, Japan, and South Korea have established formal agreements for cooperation and have held regular joint meetings. Such meetings could include India and place more emphasis on the environment.

Fourth, the United Nations and other organizations could create mechanisms for regional cooperation and governance of natural resources. Considering the number of heritage sites in the Himalayas, UNESCO and the U.N. Environment Programme, in particular, could be key in bringing the two countries together and facilitating such cooperation. Moreover, international foundations and nongovernmental organizations that are engaged in environmental issues on both sides of the Himalayas could develop transnational programs.

Fifth, the existing political and economic forums, such as the East Asia Summit and the Association of Southeast Asian Nations with China, Japan, and South Korea, which primarily foster trade, could pay more attention to the environment, which sustains most economic endeavors.

Finally, the United States, the European Union, and other developed countries could play pivotal roles in facilitating and encouraging multinational talks on climate change and related environmental problems that transcend political boundaries. The United States has good relations with China and India, but is engaged in separate discussions with each country over economic, energy, and environmental issues. Ultimately, as China and India begin to build more confidence and consensus from within, they will settle their differences bilaterally, particularly when environmental security starts to override concern for political boundaries.

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ANALYSIS

China's Great Dam Boom: A Major Assault on Its Rivers

China is engaged in a push to build hydroelectric dams on a scale unprecedented in human history. While being touted for producing lower-emission electricity, these massive dam projects are wreaking havoc on river systems across China and Southeast Asia.

BY CHARLTON LEWIS

In their search for renewable electric power, China's engineers have been building mega-dams at a rate unmatched in human history. Many far larger than the Hoover Dam on the Colorado River — which is 221 meters high and capable of generating more than 2,000 megawatts of power — are being constructed on China's greatest rivers. Best known is the Three Gorges Dam, completed in 2008, which stretches a mile-and-a-half across the Yangtze and can generate ten times the hydropower of the Hoover Dam. Yet the Three Gorges is only a fraction of China's current dam program.

View Gallery

STR/AFP/Getty Images
Water rushes through the Xiaolangdi Dam in central China's Henan province.

The government is now engaged in a new expansion of dams in great staircases, reservoir upon reservoir — some 130 in all across China's Southwest. By 2020, China aims to generate 120,000 megawatts of renewable energy, most of it from hydroelectric power. The government declares that such dams are safe, avoid pollution, address future climate change, control floods and droughts, and enhance human life.

These assertions are largely untrue. Instead, China's mega-dams block the flow of rivers, increase the chances of earthquakes, destroy precious environments and shatter the lives of millions of people. Rather than benefiting populations with non-polluting power, China's dam builders are making a Faustian bargain with nature, selling their country's soul in their drive for economic growth.

> China's dam builders are making a Faustian bargain with nature, selling their country's soul for growth.

Since the 1950s the Chinese have built some 22,000 dams more than 15 meters tall, roughly half the world's current total. During the 1990s, as economic growth surged and air pollution spurred the need for clean energy, they turned increasingly to huge mega-dams. Protests from environmentalists have helped slow some of the building in recent years. But under the 12th Five Year Plan (2011-2015) the government seems to have cast aside restraint. Opposition has been suppressed and the dam builders are now free to move forward.

About 100 dams are in various stages of construction or planning on the Yangtze and its tributaries — the Yalong, Dadu, and Min. Two dozen more will be built on the Lancang, called the Mekong in Southeast Asia, and still more on the last two of China's free-flowing rivers — the Nu, called the Salween in Burma, and the Yarlung Tsangpo, known as the Brahmaputra in India and the Jamuna in Bangladesh. All these rivers flow off the Tibetan Plateau, a geologically unstable region that averages 4,500 meters (14,800 feet) high. As they flow down through the soft, sedimentary rock, the rivers carve steep canyons, many deeper than the Grand Canyon. The risk of earthquakes is high. Probe International, a Canadian NGO, warned in April 2012 that almost half of China's new dams are in zones of high to very high seismic risk, and most of the remainder in zones of moderate hazard.

Dams themselves may cause quakes. The seasonal rise and fall of reservoirs places extra stress on nearby rock formations. When the 50-story-high Zipingpu Dam was begun on the Min River in 2001, seismologists from China's Earthquake Bureau warned that a major fault ran less than a mile away, but they were ignored. In 2007 and 2008, the reservoir filled, with major fluctuations in the water level. In May 2008, the 7.9-magnitude Wenchuan quake occurred only 5.5 kilometers downstream, killing 80,000 people. Since then, more than 50 studies have found evidence that the reservoir triggered small quakes through the fault system, culminating in the large quake.

Five years later, on April 20, 2013, a magnitude-7.0 quake occurred at Ya'an City on the same fault line. Nearly 200 died, more than 5,000 were injured, and thousands made homeless. Fan Xiao, the chief engineer of the Sichuan Geology and Mineral Bureau, believes

> Should one dam fail, the rush of water could cause dams downstream to collapse like dominos.

this quake may have been an aftershock of the Wenchuan quake, thus possibly also dam-related.

By law each proposed dam must go through an environmental impact assessment (EIA), but the process is outdated and flawed. Red tape and corruption prevail. And EIAs have generally only addressed individual projects; until recently, there have been no EIAs for dams in cascades. Since river valleys tend to follow earthquake fault lines, a series of dams down a valley may compound the risk of quakes. Should one dam fail, the rush of water could overwhelm the next dam downstream, causing dams to collapse like dominos. In 1975 the 118-meter Banqiao dam on a tributary of the Huai was breached in a heavy rainstorm. Numerous dams downstream gave way in succession to produce a lake of more than 7,300 square kilometers. Six counties were inundated. By a conservative estimate, 26,000 died in the flooding and another 145,000 in the ensuing epidemics and famine.

Several major cascades are taking shape. On the Yangtze and its upstream stem, the Jinsha, a series of some 15 dams are planned, under construction, or completed. Among them, four huge dams above the Three Gorges — including the Xiluodu, which is 280 meters high — are expected to be completed by 2020. Along the Yalong, a major tributary of the Yangtze's, a cascade of 21 major dams is planned. On the Dadu, which parallels the Yalong, there will be 17 dams, among them the recently approved 314-meter high Shuangjiangkou, only 10 meters lower than the Eiffel Tower. On the Lancang, headwaters of the Mekong, a cascade of 26 dams is planned. The still free-flowing Nu, or Salween, River will have as many as 13 dams. On a map, each projected cascade looks like a string of beads.

Although hydroelectric dams produce considerably fewer carbon emissions than coal-fired power plants, China's assertions that dams provide clean energy are substantially untrue. The rotting of inundated trees and vegetation in reservoirs emits the greenhouse gasses, carbon dioxide and methane, that rise from reservoir surfaces. Whenever water levels drop, rotting vegetation is again exposed and methane emissions increase. Estimates of emissions vary widely, depending on the climate where the dam is built, the amount and type of vegetation flooded, and the depth and age of the reservoir. Over a projected lifetime of a dam in temperate regions, emissions could be from roughly one-third to nearly two-thirds that of a natural gas plant. In warm and densely forested areas, such as China's southwest, the emissions could be higher, particularly in a plant's early years of operation. Dam building also includes indirect emissions from development of a dam site, manufacture and transport of materials and equipment, waste disposal, and, eventually, decommissioning.

> The damage dams cause to river ecosystems is immense, turning free-flowing rivers into lifeless lakes.

Nor do big dams protect from floods and droughts. They store water during the wet season and release it during the dry season, thus reversing the natural flow of rivers. Deprived of their annual inundations, downstream marshes, lakes, and wetlands dry out and can no longer absorb floodwaters. Since the Three Gorges Dam was completed, the Dongting Lake in Hunan and the Poyang Lake in Jiangxi, which once absorbed the Yangtze overflow, have shrunk dramatically, and many smaller lakes have entirely disappeared. During the record-breaking summer flood of 2010, the Three Gorges reservoir rose to 12 meters above "alarm level." To protect the dam, its operators opened the floodgates to the maximum. Downstream some 968 people were killed, 507 more were missing and economic losses totaled $26 billion. The great dam survived its first test, but its floodplain is unlikely to contain big floods in the future.

STR/AFP/Getty Images
The Three Gorges Dam, which opened in 2008, is the world's largest producer of electric power.

Drier floodplains intensify droughts; when rivers diminish, dam operators preserve their hydropower potential by withholding water. During the January to April 2011 drought, water levels in the Lower Yangtze valley dropped steeply, stranding thousands of boats and creating power shortages in central and eastern China. On the upper reaches of the Yellow River to the north, a string of large dams has exacerbated recent droughts on the North China Plain. In addition, as the planet warms, glacial melt will diminish river flows, reservoirs will not fill, and dams may then prove to be a colossal boondoggle.

The damage that dams cause to river ecosystems is immense, turning free-flowing waterways into lifeless lakes, killing plants and trees, blocking fish migration and breeding, driving species to extinction, and devastating established patterns of human life. A looming example of such disruption is the threat hanging over the Three Parallel Rivers area in Yunnan Province, where the Jinsha, Lancang, and Nu flow through separate gorges as deep as 3,000 meters in an area less than 75 kilometers across. Declared a World Heritage Site by UNESCO in 2003, this spectacular region is one of the most environmentally diverse and fragile on earth. Hydropower companies are now planning some 25 dams in this zone.

The Xiaonanhai Dam, to be constructed above the Three Gorges reservoir, will sever the last remaining migratory route that fish need in order to reproduce, including rare and endemic species such as the paddlefish (the biggest freshwater fish in the world) and the Dabry's sturgeon, whose numbers have already been drastically reduced. The Chinese river dolphin was declared extinct in 2006.

Dams also pollute. Their reservoirs capture chemicals, fertilizer runoff, human waste and all kinds of trash. During the 2010 flood, floating refuse backed up behind the Three Gorges Dam over an area of more than 50,000 square meters, so thick, according to the *Hubei Daily* "that people can literally walk on the water's surface." Without annual floods, dammed rivers fail to flush contaminants downstream. As the rivers percolate into the ground, they deliver pollutants into the aquifers — this in a country where nearly 60 percent of groundwater in 198 cities has been measured as poor, according to a report this year by the Ministry of Land and Resources.

During the last 50 years, 16 million Chinese have been relocated to make way for hydro projects.

Dam reservoirs trap silt, which decreases their storage capacity and reduces power generation. Silt no longer carries nutrients down the rivers, and without protective silt, salt water encroaches on estuaries and damages croplands. Estuaries also become more vulnerable to rising sea levels.

Great dams also devastate human populations. During the past half-century about 16 million Chinese have been relocated to make way for hydroelectric projects, and of these 10 million live in poverty, according to *China Youth Daily*. With each new project, communities are fractured and lives disrupted. People are relocated to new towns or forced to resettle on degraded land. Often they do not receive promised resettlement money or job training, driving many to migrate again. The Three Gorges Dam alone has submerged 13 cities, 140 towns, and 1,350 villages. By 2007 its reservoir had displaced some 1.4 million people.

When the two-football-fields-high Pubugou dam was built on the Dadu River between 2001 and 2010, 100,000 persons were driven from their homes. Evictions began even before final approval in 2004. Tens of thousands rioted against the dam, reportedly one of the largest rural demonstrations since the founding of the People's Republic of China.

China's dam projects also threaten livelihoods in other countries. Of the watersheds discussed above, only the Yellow and the Yangtze are wholly domestic. Outside of China the Lancang/Mekong, Nu/Salween, and Yarlung Zangbo/Brahmaputra flow through several countries of Southeast Asia, India, and Bangladesh. Since 1997 China's government has declined to sign the United Nations water-sharing convention that would govern its major transnational rivers, yet it continues to build dams without consulting its downstream neighbors.

'These projects will be a source of permanent grief and regret for future generations,' says a Chinese geologist.

On the Mekong, China's dams are affecting agriculture and fisheries. In Laos and Thailand, crops are regularly washed away before harvest time as upstream dams release their water. Nutrient-rich silt no longer reaches the Mekong delta, which is reducing fish stocks. In Burma and Thailand, environmental groups have spoken out about the threats to wildlife and populations from dams now planned for China's Nu/Salween. A colossal 38,000-megawatt project has been proposed at Motuo on the Yarlung Tsangpo in Tibet. The project would pose a serious threat not only to the Tibetan Plateau but to India and Bangladesh, where the Yarlung becomes the Brahmaputra and Jamuna rivers.

China's unprecedented construction of dams makes a mockery of the larger vision expressed in its current Five Year Plan to develop clean energy, reduce pollution, and protect the environment. A more accurate vision may be that of the Sichuan geologist Fan Xiao in his 2011 letter opposing the Xiaonanhai Dam.

"These major projects will be synonymous with the worst excesses of this era, and the mark they will leave in history is going to be very difficult to erase." Fan goes on to warn that the great dams will become "a source of permanent grief and regret for future generations yet unborn."

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What Happens When Asia's Water Tower Dries Up?

Drought in the Yunnan province of China affects most of the major rivers of Asia

Apr 16, 2013 | By Coco Liu and ClimateWire

LIJIANG, China -- After photographing Black Dragon Lake here for eight years, He Jiaxin knows of more places where he can get the lake to mirror the majesty of its surrounding mountains than anyone else. But this year, he has a problem: The lake has disappeared.

Flickr/Winston Smith

Since its springs dried up last year, no water has flowed into Black Dragon Lake for more than 400 days. At the same time, hot weather caused a high evaporation rate, turning a large part of the lake into a play yard for children.

"I've never seen such a dry-up before," He, a 36-year-old local photographer, said while staring at the parched lake bed. "It hasn't rained in Lijiang for a really long time."

Lijiang is hardly alone. Similar situations are happening across other parts of Yunnan province, which usually has more rain than half of China's regions. But it has experienced extremely low rainfall for the past three years.

In the first quarter of this year, Yunnan's average rainfall dropped by 70 percent, indicating the start of the drought's fourth consecutive year, according to the water resources department in the region.

As national demand for Yunnan's hydroelectricity and other products keeps rising, the region is losing one of its most abundant resources -- water -- to produce them. The

province is scrambling to adopt measures that would ease water stress, with mixed results. Meanwhile, its fast-growing population and economy are adding more water security problems.

Already, "when we look into the annual precipitation index we use, we can see that there has been no 'wet' month in Yunnan in the last four years," said Marco Gemmer, a senior adviser of the China Meteorological Administration in Beijing.

"The length and intensity of the drought is larger than we have recorded in the past 60 years," he added.

Forecast: more extreme weather and less relief

Gemmer attributes the record drought to changed atmospheric circulation, with less water transported in 2009 from the Gulf of Bengal, where Yunnan's rainfall is generated, being a prime example. Other reasons include a warmer climate than usual.

"The atmosphere is a complex system, and small changes can have an effect at the other end of the globe," Gemmer explained. "Assuming that there will be further changes in the atmospheric system under global warming, we should be prepared for more unusual events in the future, which could also include extremely wet conditions causing floods or landslides."

Meanwhile, Yunnan is losing an ally that once helped absorb such changes. To boost the local economy, the region has been replacing its natural forests with more commercial trees like eucalyptus plantings on a large scale.

As bushes and other vegetation are cleared as part of that process, forests have a weakened ability to lock in rainwater, according to a study released this year by Greenpeace. In one county of Yunnan, the report notes, water reserves close to commercial forests dried up, while 30 miles away water was plentiful because natural surrounding forests remained uncut.

So if Yunnan continues to replace its natural forests, Greenpeace warns, the region's forestry sector will no longer be able to conserve as much water when rainfall runs low.

'The hardest time in my life'

That's a thing Yang Zhikun definitely does not want to happen. Living in a village without modern infrastructure, Yang's family relies on springs for water, but because of the recent drought there has been no water flowing into his household tank for more than 20 days.

Yang explained that he has to borrow water from distant neighbors. And if rain still doesn't come this month when the tobacco growing season begins, Yang faces a bigger challenge.

In Yang's village of Longba, rainwater used to be sufficient to keep his mountaintop tobacco fields green. But since 2009, rain has gone missing, and Yang had to start carrying water up from a river several miles away.

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Last year, the amount of water needed for irrigation was so big that everyone in Yang's family went to help, including his teenage children and parents in their late 70s. Still, about a fifth of the tobacco seedlings he planted withered for lack of water. Replanting added more to the workload and the difficulties to make ends meet.

"That was the hardest time in my life," the 40-year-old tobacco grower recalled. "I don't know how to make a living if the drought continues into this year."

Yang is not alone. On the provincial level, the drought has already baked millions of acres of farmland over the past three years, leaving many farmers with nothing to harvest.

The financial disaster has spread to businesses that trade and process agricultural goods. For instance, many rubber factories in Yunnan reportedly shut down due to insufficient raw materials. This, combined with declining revenue in other industries, has caused a direct economic loss of about $4.2 billion in Yunnan since the drought started in 2009, local media have reported.

Little water left to 'help the nature'

There is also a national impact. Yunnan is a major Chinese herb-growing area, and its falling output drove up herb prices nationwide. The drought has also hampered China's ability to transmit hydroelectricity from water-rich western regions to feed the country's power-hungry manufacturing sector, most of which is in the east.

Meanwhile, the province's forests are on high alert because of the threat of wildfires. The drought has also dried up many lakes and wetlands, causing die-offs of aquatic species and forcing survivors to live in more polluted waters.

In Fuxian Lake, a sharp water level drop has already shrunk the habitats of a type of fish that only exists there, said Duan Changqun, an ecologist at Yunnan University. He added that changes to one species will have a significant impact on the whole ecosystem.

For now, no one knows what that impact will be. A complete analysis on the effects of Yunnan's drought is still missing, and some damage may not emerge for years.

"Yunnan is known as Asia's water tower because many important domestic and international rivers start from here," Duan explained. "Droughts in Yunnan mean less water flows in the downstream, sending a blow to ecosystem of other parts of China as well as South Asian countries."

Some steps have been taken in recent years to protect Yunnan's drought-stricken environment, such as strengthening fire prevention measures in forests. But Duan says those efforts are negligible compared with what is needed.

"The priority is given to ensuring drinking water, and then supporting agricultural and industrial water use," he said. "Little water is left to help the nature."

'Why bother to plant?'

Yet even for residents, who enjoy the most support, getting water is becoming harder.

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Due to years-long intensive use and a lack of refilling, water levels in many reserves run low and cities like the provincial capital, Kunming, had to cut water supplies for households to four hours a day.

Empty water reserves also made villagers hesitate to continue farming. In Longba village, the number of tobacco growers is decreasing. "Villagers believe they will not be able to get enough water for their fields, so why bother to plant?" explained Duan Shaokun, a local official.

As one grower quits, then another and another, remaining growers begin to feel the pain of a smaller community -- tobacco companies are not willing to subsidize water-saving technologies and invest in more efficient irrigation systems because of the limited scale there, Duan Shaokun says. And villagers themselves can't afford the hefty upfront investment.

So the government in Yunnan moved in to help. Through 2015, multibillion-dollar investment will be poured into constructing new water reserves of 3 billion cubic meters -- a nearly 30 percent increase in Yunnan's 2009 capacity. But experts say this may still not be enough.

"Yunnan is facing a structural challenge," said Gemmer, the Meteorological Administration senior adviser. "The current development and economic structure cannot be maintained because it will be impossible to protect all 45 million citizens of Yunnan from droughts."

The region's population already increased by 12 percent and economic output per capita quadrupled since 2000, but the available water resources per capita have dropped by half, Gemmer added.

Adaptation gets harder

Yunnan has been trying hard in recent years to overhaul its resource-intensive economy and turn to industries that use less water, but now that plan is at risk.

Lijiang, for one, has bet its economy restructure on tourism. In 2010, millions of travelers came to experience its beautiful lakes, gorges and snow-capped mountains, bringing revenue of more than $1.8 billion. But with a changing climate and persistent drought, that's gone, too.

"I wouldn't have had time to talk with you at this time in previous years, but now I waited here for hours and saw only a few visitors," said He, the photographer who makes a living by taking pictures for tourists near Black Dragon Lake.

Lijiang is now building a channel to bring in water from a nearby water reserve, but this can only refill part of the lake. Worst of all, global warming is causing glaciers, which supply most of Lijiang's water, to melt faster.

According to a recent study by the Meteorological Administration, glaciers in Mount Jade Dragon began retreating in the 1980s, and more than 70 percent of glaciers there are expected to disappear if the average temperature rises more than 1.6 degrees Celsius from now to 2050.