Synopsis

This synopsis was not peer reviewed.

Comparative Assessment of Soil Properties after Bamboo Flowering and Death in a Tropical Forest of Indo-Burma Hot Spot

The general impact of unregulated shifting cultivation in the tropics altered the landscapes that were once large tracts of evergreen dense primary forests into fragmented mosaics of small habitat islands of degraded primary forests, secondary forests, and low quality bamboo forests (1, 2). After slash and burn agriculture (jhum) at lower elevations in northeast (NE) India, the secondary succession passes from a herbaceous weedy community to a bamboo forest (2).

Bamboo is a predominant understory species in forest ecosystems of NE India (2). Out of the 150 species of bamboo available in India, 58 are present in NE India (3). Bamboo is an important commercial source for a variety of purposes, such as manufacture of paper; construction of houses, bridges, furniture, bags, and baskets; and use as, although to a limited extent, fuel and fodder (4). Others (5) also mentioned the economic importance of bamboo in the form of food (young shoot), timber, and agricultural implements (culms and branches) in three states (Mizoram, Meghalaya, and Sikkim) of NE India. Bamboo is also inextricably linked with the traditional culture of peoples of NE states, particularly Mizoram, and various festivals are based on it with the performance of the bamboo dance. Therefore, in real sense, bamboo is poor's man timber in the NE states of India. However, one menace occurred from 2005–2006 in NE India in the form of famine, resulting from an increase in the numerical strength of rodents after synchronous bamboo flowering.

Bamboo shows a characteristic simultaneous mass flowering after long intervals of several decades (6). Bamboo species flower suddenly and simultaneously, then all the flower clumps die, leading to drastic changes in forest dynamics and environmental conditions, for example, light intensity, seedling survival, organic matter decomposition, and nutrient cycling, although complete destruction of bamboo clumps requires another few years (7). Bamboo communities follow active nutrient cycling, and their vigorous growth and litter production ameliorates nutrient impoverished coal mine spoil and tropical soil fertility (2, 4, 8). However, after mass flowering and death, nutrient uptake by the bamboo ceases and large amounts of dead organic matter are deposited.

Several studies emphasized the role of bamboos in soil nutrient conservation (2, 4, 9). Also, bamboos in the early successional fallows of slash and burn agriculture systems of NE India are very important in stabilizing nutrient cycling (2, 9). However, there is very little information on the impact of bamboo flowering on soil properties. Henceforth, in the present study, I confined my quest toward the impact of the flowering bamboo stand on soil fertility. Likewise, the present work attempted to investigate whether soil fertility declines after bamboo flowering because of the disruption of nutrient cycling or is it maintained because of release of nutrients from decomposing organic matter. Further, the findings may be relevant in relation to plant growth and vegetation succession. We therefore examined the surface soil nutrient status and microbial population of sites after bamboo flowering compared with those with living bamboo species in a seasonal tropical forest in a NE state of India.

Northeast India forms a significant portion of both the Himalaya and Indo-Burma biodiversity hotspots (10–12). The study area was Mizoram, the 23rd state of the Indian union; it covers an area of 21 087 sq km and is sandwiched between Myanmar (Burma) and Bangladesh (3). The vegetation of Mizoram, according to proposed classification (13), is tropical evergreen and semi-evergreen forest in the lower altitude hills; subtropical to montane subtropical in the high hills. A major portion of Mizoram's forests are therefore tropical evergreen and semi-evergreen. The sampling site (23°45′ and 24°31′N latitude and between 92°16′ and 93°26′E longitude at an elevation of 850 m above mean sea level) was located in peri-urban settlement of Western Aizawl (3 km away from Mizoram University), the capital of Mizoram, and samplings were performed along a hilly transect varying across slope gradient. The climate was humid tropical, characterized by short winters and long summers with heavy rainfall. During the summer season, the temperature generally varies from 21°C to 35°C, while the winter temperature ranges from 4°C to 23°C. The rainfall period generally ranges from April to October. The peak rainfall during the investigation period was recorded as 550 mm. As mentioned earlier, because of the frequent practice of shifting cultivation, bamboos form the major secondary successional vegetation component along with some trees and herbaceous weeds, prominently *Lantana camara.*

In 2007 (during the month of October), approximately 1 year after flowering, two quadrats (20 $\times$ 20 m^2) were placed in triplicate along a slope gradient approximately 100 m apart. One quadrat in each plot was placed in a site with dead bamboo (DB site) and the other in a site with living bamboo (LB site). The LB site comprised nonflowering stands of *Bambusa tulda*, *B. khasiana,* and *Dendrocalamus hamiltonii* whereas flowering stands of *Melocanna baccifera syn. bambusoides* (common name moutak, i.e., death causing because of associated famine and plague) were present at the DB site along the slope gradient. Because flowering is simultaneous, utmost care was taken to differentiate flowering stands of *M. baccifera* from other live or nonflowering bamboo species.

Five replicates of surface soil (0–10 cm), litter, and ground vegetation samples were collected from the corners and center of each quadrat. The litter layer and herbaceous ground vegetation in a 100 $\times$ 100 cm^2 frame were collected, dried at 70°C for 1 week in an oven, and then used for biomass estimates. The moist surface soil samples were dried at 105°C in an oven for determination of soil moisture content.

Part of the moist soil samples were air-dried and sieved to obtain fine soil samples (<2 mm). Soil pH was measured with a soil–water (1 : 5) slurry using a pH glass electrode. Organic carbon was determined according to the Walkley and Black method, total nitrogen was determined using the Kjeldahl method, and available phosphate was extracted using the Bray method. All analyses were conducted as per the methodology described elsewhere (14). To determine potentially available nitrogen (NH^{4+} and NO^{3-}), the steam distillation method was used. The extent of nitrification was expressed as the percentage of mineralized NO^{3-} in total mineralized nitrogen.

For the estimation of microbial population and biomass, another set of three soil samples (0–15 cm depth) were collected. In this case, the corer was wiped with absolute ethanol before every insertion to prevent any external microbial contamination. The bacterial and fungal popula-

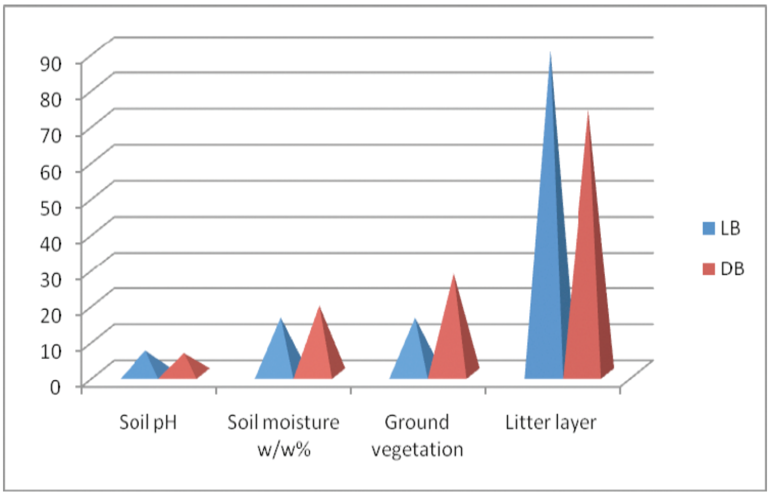

Figure 1. Soil pH, soil moisture, ground vegetation (g m^{-2}), and litter layer (g m^{-2}) at the live and dead bamboo sites (LB and DB) (average of five replicates).

tions were determined using dilution plate techniques on nutrient agar and rose bengal agar medium, respectively. Soil bacterial population was estimated by Waksman's (15) method using nutrient agar medium. Fungal population was estimated by the dilution plate method (16) using Martin rose bengal agar medium at 103 dilution in water. Microbial N, C, and microbial P were estimated by the chloroform fumigation extraction method (17).

SPSS 11.5 was used for statistical analysis. Analysis of variance was used to evaluate the impact of bamboo death on soil chemical properties. Least significant difference at 95% confidence level was used to compare the mean values across both sites.

The average values of soil properties are represented in Figures 1 and 2. Soil pH (6.4 at the LB site; 5.7 at the DB site) was slightly acidic at the DB site. Soil pH may play an important role in the biogeochemistry of soil and may affect the uptake of exchangeable ions, particularly Ca and Mg. Soil moisture (15.6 at the LB site; 18.9 w/w% at the DB site) values were recorded higher at the DB site, but the difference was not significant. The litter layer (90 g m^{-2} at the LB site; 73.5 g m^{-2} at the DB site) showed no significant difference between litter mass at both the sites, although all leaves of *M. baccifera* became senescent, subsequently falling and accumulating at the DB site. The opposite trend may be attributed to the high litter decomposition during the rainy season, making the litter layer less available. Ground vegetation (15.5 g m^{-2} at the LB site; 27.8 g m^{-2} at the DB site), mostly germinated bamboo seedlings and *L. camara* (an exotic invasive species), was greater at the DB sites than the LB sites. At the LB site, less vegetation occurred because of shade imposed from the growing bamboo canopy (Fig. 1).

Soil organic carbon content was significantly lower in the DB site than the LB site (Fig. 2). Likewise, available N and P were relatively low in the DB site compared with the LB sites, although the differences were not significant. However, the nitrification rate was unaffected by the impact of bamboo flowering (Fig. 2).

The microbial population was also higher at the LB site (bacterial: 13.596×10^5 g^{-1} dry soil and fungal: 67.889×10^3 g^{-1} dry soil). However, the recorded CNP was higher in the soil of the DB site (Table 1).

Results of the present research revealed that total soil nitrogen, available nitrogen, and P content were low in sites where bamboo had flowered and died. In general, the surface soil in the DB (*M. baccifera*) sites was comparatively more infertile than that in the LB sites, although a large amount of dead organic material (for example, leaf litter, broken culms, and root litter) was deposited after bamboo death. This suggests that nutrient conditions declined within a year after bamboo flowering and death. Thus, the soil physicochemical properties of the tropical forest are probably maintained by bamboo species through nutrient and carbon cycling, as demonstrated by several previous workers (2, 8, 9). Further, opening of the canopy through the death of bamboos may increase the penetration of light and hence temperature. Increase in temperature coupled with more soil moisture might have decomposed the fallen litter within 1 year after flowering.

Except for soil carbon content observed at the DB site, the rest of the soil properties have not varied significantly when compared with the LB site. Because N and P in the surface soil largely follow the dynamics of soil organic matter, the effects of bamboo death on N and P soil content should also be negligible in the short term (7).

Comparatively lower nutrient content might be responsible for the decrease in the microbial population at the DB site. Also, bamboo death seems to affect the labile fraction, which is related to the existence of the bamboo community, probably through leaf and root litter turnover (7). Their finding suggested that the labile nutrients available for microbial activity are reduced after bamboo death. However, persistent nutrient allocation between soil and microbes might have resulted in a comparatively higher microbial biomass at the LB site. This finding corroborates the other group (4), who reported that soil microbial biomass and available N increased with the development of the bamboo community on mine spoil soil. Further, in contrast with the soil nutrient status, microbial biomass showed comparatively higher CNP content, which might be due to the more microbial immobilization in nutrient poor conditions. This finding is in accordance with a previous finding (18), which suggested a reciprocal relationship between microbial biomass and plant growth in nutrient poor ecosystems.

CONCLUSION

Bamboo flowering and death lead to a decline in nutrient status and microbial

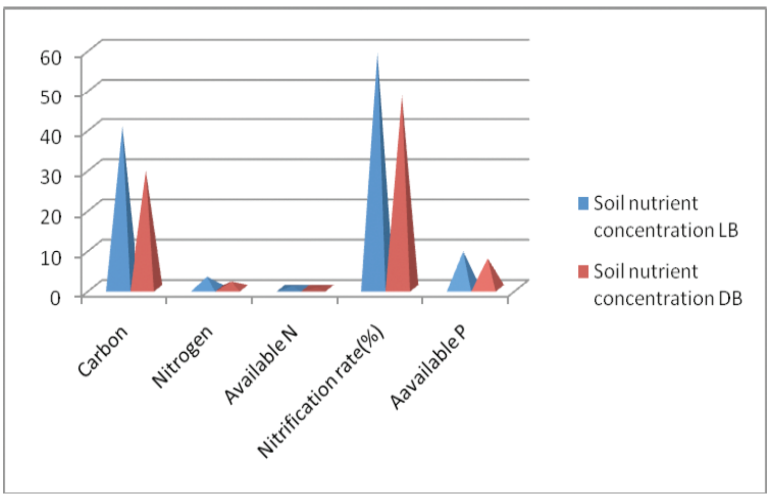

Figure 2. Soil organic C content (g kg^{-1}), total N content (g kg^{-1}), available N content (mg kg^{-1}), nitrification rate (%), and available P content (mg kg^{-1}) at live and dead bamboo (LB and DB) sites (average of five replicates).

Table 1. Soil microbial population and CNP (carbon, nitrogen and phosphorus) content in microbial biomass.

Site	Population: Bacteria (number of colonies × 10^5 g^{-1} dry soil)	Population: Fungi (number of colonies × 10^3 g^{-1} dry soil)	Biomass ($\mu g\ g^{-1}$) C	N	P
LB site	13.596	67.889	248.561	176.891	6.443
DB site	6.937	77.899	376.931	233.00	7.982
LSD at 0.05 level	1.63	23.9	179.88	63.00	2.70

population. High nutrient concentrations (CNP) recorded in microbial biomass at the DB site revealed that microbial biomass acts as source and sink for plant nutrients in nutrient-poor ecosystems. Higher nutrient status and microbial population in the LB stands offer its scope for reclamation of nutrient impoverished agroecosystems and agroforestry systems, particularly those that have undergone shifting cultivation with a less fallow period. The impact of individual bamboo species should also be monitored in future researches. Henceforth, further study is needed to completely analyze and understand the consequences of bamboo death on soil parameters, microbial biomass, and nutrient cycling.

References and Notes

1. Mertz, O., Wadley, R.L., Nielsen, U., Bruun, T.B., Colfer, C.J.P., Neergaard, A., de, Jepsen, M.R., Martinussen, T., et al. 2008. A fresh look at shifting cultivation: fallow length an uncertain indicator of productivity. *Agric. Syst. 96*, 75–84.
2. Rao, K.S. and Ramakrishnan, P.S. 1989. Role of bamboos in nutrient conservation during secondary succession following slash and burn agriculture (jhum) in north-east India. *J. Appl. Ecol. 26*, 625–633.
3. Lianzela 1997. Effects of shifting cultivation on the environment: with special reference to Mizoram. *Inter. J. Social Econom. 24*, 785–790.
4. Singh, A.N. and Singh, J.S. 1999. Biomass, net primary production and impact of bamboo plantation on soil redevelopment in a dry tropical region. *For. Ecol. Manag. 119*, 195–207.
5. Bhatt, B.P., Singha, L.B., Singh, K. and Sachan, M.S. 2003. Commercial edible bamboo species and their market potential in three Indian tribal states of North Eastern Himalayan Region. *J. Bamboo Rattan 2*, 111–133.
6. Wong, K.M. 2004. *Bamboo: The Amazing Grass-A Guide to the Diversity and Study of Bamboos in Southeast Asia*. IPGRI and University of Malaya, Kuala Lumpur, Malaysia.
7. Takahashi, M., Furusawa, H., Limtong, P., Sunanthapongsuk, V., Marod, D. and Panuthai, S. 2007. Soil nutrient status after bamboo flowering and death in a seasonal tropical forest in western Thailand. *Ecol. Res. 22*, 160–164.
8. Mailly, D., Christanty, L. and Kinunins, J.P. 1997. 'Without bamboo, the land dies': nutrient cycling and biogeochemistry of a Javanese bamboo *tahn-kebun* system. *Forest Ecol. Manage. 91*, 155–173.
9. Arunachalam, A. and Arunachalam, K. 2002. Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: ground vegetation, soil and microbial biomass. *For. Ecol. Manage. 159*, 231–239.
10. Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature 203*, 853–858.
11. Mittermeier, R.A., Gil, R.P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and da Fonseca, G.A.B. 2004. *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecosystems*. Cemex, Mexico.
12. Conservation International. 2005. *Biodiversity Hotspots*. Conservation International, Washington, DC. (http://www.biodiversityhotspots.org/xp/Hotspots/)
13. Champion, H.G. and Seth, S.K. 1968. *A Revised Survey of the Forest Types of India*. Government of India Publication, New Delhi, India.
14. Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice-Hall Inc., Englewood Cliffs, NJ.
15. Waksman, S.A. 1952. *Soil Microbiology*. Wiley, New York.
16. Johnson, L.F. and Curl, E.A. 1972. *Methods for the Research on Ecology of Soil-borne Plant Pathogens*. Burgess Minneapolis.
17. Anderson, J.M. and Ingram, J.S.I. 1993. *TSBF—Handbook of Methodology*. CAB International, Wallingford.
18. Singh, J.S., Raghuvanshi, A.S., Singh, R.S. and Srivastava, S.C. 1989. Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. *Nature 399*, 499–500.

19. The author is thankful to Dean, Mizoram University, for providing the necessary facilities and Professor A. N. Rai, Vice Chancellor, Mizoram University for encouragement and support.

Prabhat Kumar Rai
Department of Forest Ecology Biodiversity and Environmental Science
Mizoram University Tanhril Campus
Post Box N. 190 Aizawl, India
Pin code 796001 Gram; MZU
prabhatrai24@yahoo.co.in

Synopsis

This synopsis was not peer reviewed.

How Can the Clean Development Mechanism Better Contribute to Sustainable Development?

In the December 2007 climate conference in Bali, Indonesia, delegates defined a trajectory for international climate policy that extends beyond the Kyoto Protocol's expiry in 2012. During the 11 December meeting was the 20th anniversary of the Brundtland Commission's 1987 report *Our Common Future*, which famously crystallized a vision of sustainable development that implies "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (1). No issue may be more central to planetary sustainability than humankind's modification of the Earth's climate (2).

Yet the concept of sustainability is essential not only to impel action on emissions reductions but also to foster agreement on the process: In all past and ongoing climate negotiations, a keystone of consensus is the idea of "common but differentiated responsibilities"—parallel and equitable action toward the goals of human and natural well-being. While this foundational idea, echoed again in the Bali Action Plan, stems from environmental discussions in the 1980s, the principles underpinning it are likely to be perpetual: given the voluntary nature of international law, the obligations for different countries must necessarily acknowledge the variety of economic weight, historical and present contribution to atmospheric emissions, and vulnerability to climate impacts.

While the overall success of the Kyoto Protocol remains debated (3), the treaty has unequivocally driven the creation of a number of market-driven institutions for emissions reductions, which include the Clean Development Mechanism (CDM) (4). As of late 2008, the CDM was responsible for spurring over 4300 projects in 70 developing countries (5). These projects are expected to reduce global greenhouse gas emissions by up to 5.5 Gt CO_2-

equivalent by 2020 and the continuation of a similar market framework after 2012 could result in larger numbers. While such reductions are but a fraction of the cuts needed to halt the rise of global temperatures, the annual growth in CDM volumes can be seen as a partial success in a regime with otherwise limited demonstrable progress toward its stated goals.

Yet the CDM was originally conceived not only as a tool to mitigate climate change. It was proposed by a group of developing countries as the compromise that allowed for their economic growth within environmental constraints. It was envisioned that developing countries could accrue benefits for sustainable development from carbon markets while simultaneously addressing greenhouse gas emissions. The treaty language, in fact, places sustainable development benefits *on equal footing* with emissions reductions, and developing nations saw an opportunity to bring substantial investments and new technology to foster sustainable growth through CDM projects. The industrialized countries were willing to participate because the CDM offered a cost effective alternative to domestic emission reductions.

The perceived tension between these two goals—market efficiency in lowering emissions and nonmarket improvements in human welfare and local environment—has raised questions about the potential for climate policy simultaneously to promote sustainable development. On the one hand, the CDM has achieved cost effective emissions reductions in developing countries on a large scale. However, by some metrics, the CDM has fallen short on this dimension. While stimulating a great number of projects, the distribution of these projects has been geographically uneven, weighted toward larger countries, and dominated by a few sectors (see Fig. 1). China, for example, has captured 65% of the Certified Emission Reductions (CER) market, while Africa has gained little from technology transfer with only 4% of projects to date and only 3% of the volume. Overall, the top five countries (China, India, Brazil, Mexico, and Malaysia) account for 79% of the total volume (5). Projects focused on eliminating industrial gases, including hydrofluorocarbons, perfluorocarbons, N_2O, and methane account for 75% of the credits issued thus far.

Sustainable development is left undefined in the UN Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and all the ancillary documents that have followed from years of negotiations. Each host country can therefore interpret sustainable development for itself, a provision stemming from Principle 21 of the 1972 Stockholm Declaration. For example, the mechanism might contribute to local environmental benefits, job growth, income equity, technology development, or additional energy infrastructure in developing nation economies.

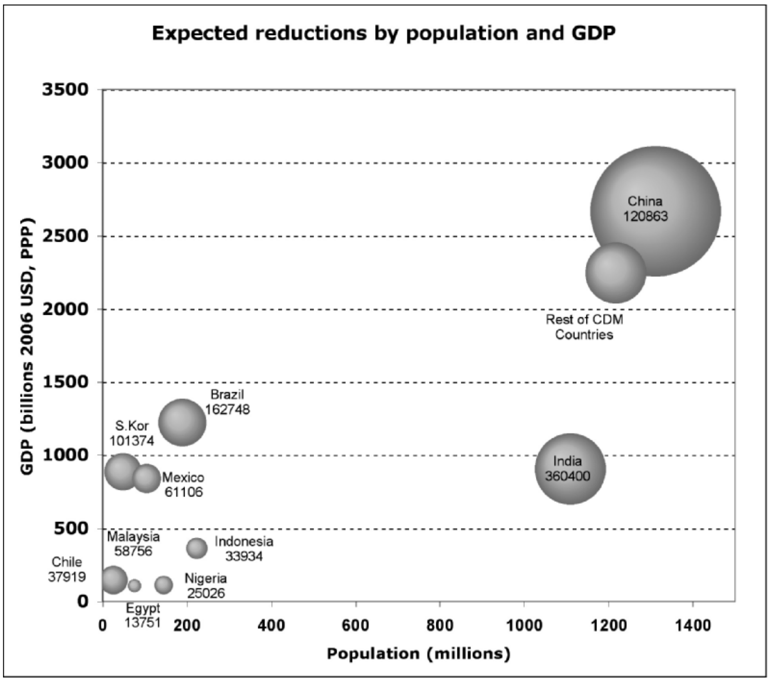

Figure 1. CDM emissions reductions (in kilotonnes CO_2 equivalent) expected by 2012, plotted by population and GDP. Data from UNEP Risoe CDM/JI Pipeline Analysis and Database, November 2007.

Nations have accordingly approached CDM sustainability in different ways. Because governments are responsible for certifying sustainable development, critics suggest a potential conflict of interest between national governments' overall desire for foreign investment and the needs of local communities who may be affected by a project (6, 7). The extent to which local stakeholders may comment on proposed CDM activities or benefit from CDM projects is highly dependent on structures of local governance and opportunities for participation (8).

In some large-scale CDM projects with very few direct benefits to local people, developers have had to commit to use a percentage of CER revenues to fund local development projects (9, 10) such as new roads, training programs, health centers, and employment-generating initiatives. Some projects have also increased local employment and improved local air quality, though these benefits have been modest (11). For smaller projects with a focus on community development, however, potential carbon revenues are often insufficient to cover the high transaction costs involved in the development and verification of CDM projects (12). In part, this crowding out of sustainability stems from the interest of buyers in low-cost emissions reductions. Given the current architecture, therefore, the CDM's contribution to sustainable development has been and is likely to remain limited (13).

This need not be the case, however. The CDM already links markets to wider poverty agendas. It potentially provides a model for integrating sustainability into development finance, a goal which has been frequently stated but only imperfectly achieved. Leaders of wealthy nations have repeatedly made promises of large-scale international financial assistance for developing countries, from the 0.7% of gross domestic product (GDP) claim made in the 1970s to the Gleneagles Plan of Action promise of an additional USD 50 billion in aid to Africa by 2010. The "Grand Bargain" at Rio included promises of USD 141.9 billion a year in additional funding from the global North for sustainable development, of which USD 15 billion was to be devoted to global environmental issues like climate change. However, these promises have largely failed to materialize. Some voluntary funds, including the three established under the UNFCCC, have received only modest donations. Since the mid 1990s, the level of multi- and bilateral environmental donor funding has totaled about USD 8–10 billion, and most of this has been spent on water and sewage projects (14). After years of negotiations, the CDM now includes an "adaptation levy" of 2% of revenues from the sale of Certified Emissions Reductions, providing the first dedicated tax base of funds from North to South of approximately USD 300 million from 2010–2012. In addition, USD 7.9 billion in carbon finance were created under the CDM in 2006 alone and this figure is expected to grow steeply in the years to come.

A future framework might allow for the aggregation of individual projects to reduce transactions costs. Current proposals for reducing emissions from deforestation and the use of development aid to foster local capacities, for example, would reduce project transaction costs through aggregation (15, 16). First, an expanded investment framework could also allow work with development institutions in sectors and regions where CDM investments are more likely to lead to substantial development benefits. For example, these could draw upon public investment guarantees, capacity building, rural electrification with renewable energies, or landfill gas capture and storage. Second, improving the governance of regions with the greatest need for poverty-reducing investments would also address one of the foremost investment risks for CDM project developers, while laying the groundwork for real and diversified sustainable development in the regions. Third, experiences from voluntary carbon markets demonstrate possible means to channel demand from carbon buyers to projects that contribute to local development (17). Internationally agreed voluntary standards for sustainable development–CDM projects could help differentiate such projects and give them an advantage in the marketplace and build experience for more universal requirements. It has also been proposed that the system for awarding CERs to projects might also be adapted to promote and reward projects that generate significant sustainable development benefits or involve investment in the world's least developed countries. Fourth, following China's model, host developing nations may also consider taxing carbon finance revenues of CDM projects differentially depending on the projects' contribution to sustainable development. Fifth, the promotion of technologies within the CDM that specifically benefit the rural sector and less industrialized countries could correct some of the systemic imbalances in the current architecture and incentive structure. For example, avoided deforestation activities, agroforestry, and improved efficiency cooking stoves could benefit precisely those people and countries that have until now been disadvantaged by the CDM's focus on industrial technologies.

Should international climate policy instruments such as the CDM encompass broader sustainable development goals, or should they focus exclusively on utilizing market efficiencies to bring about as many emission reductions as possible? Sustainable development, being a politically central but poorly executed tenet in the CDM, is currently not incorporated into its core incentive structure. In the current system, any additional, noncarbon specific requirements are likely to increase costs. Similarly, it is logical that private investors focus their efforts on countries that pose lower political and economic risks for their projects, or who impose weak sustainable development criteria, and the CDM is no different in this regard from other forms of foreign investments.

Yet two principles will always lie at the heart of successful international climate policy: first, diverse countries will have "common but differentiated responsibilities" for climate protection; second—as articulated in the Brundtland report but present from Stockholm to Rio and Kyoto—environmental goals must be pursued in partnership with economic growth. Divorcing sustainable development from the CDM—and not including them elsewhere—could remove incentives for broad-based participation. The experience of the past 20 years of contested international policy underscores the importance of policies that command the confidence of a majority of countries, both developed and developing. Therefore, parallel action from all countries—especially the largest emitters—will be needed to unlock action on climate change. Ensuring broad-based participation in climate governance requires that the overall architecture be perceived as fair and beneficial to the development goals of all countries. Yet at the same time, structural reforms should respect the preliminary success of the CDM in stimulating market innovations. Enhancing sustainability in the international architecture of climate protection is a critical element in policy that will encourage the parallel, differentiated actions needed to protect our common future.

References and Notes

1. World Commission on Environment and Development. 1987. United Nations General Assembly, New York.
2. Bouwer, L.M., Crompton, R.P., Faust, E., Höppe, P. and Pielke, R.A. Jr. 2007. Disaster management: confronting disaster losses. *Science 318*, 753.
3. Prins, G. and Rayner, S. 2007. Time to ditch Kyoto. *Nature 449*, 973–975.
4. Wara, M. 2007. Is the global carbon market working? *Nature 445*, 595–596.
5. Fenhann, J. 2008. *UNEP Risø CDM/JI Pipeline Analysis and Database*. United Nations Environment Programme, Risø Centre, Risø, Denmark.
6. Lohmann, L. 2001. Democracy or carbocracy? Intellectual corruption in the debate over climate change. *Watershed 7*, 20–35.
7. Pearson, B. 2007. Market failure: why the clean development mechanism won't promote clean development. *J. Cleaner Prod. 15*, 247–252.
8. Boyd, E., Gutierrez, M. and Chang, M. 2007. Adapting small-scale CDM to low income communities. *Glob. Environ. Change 17*, 250–259.
9. Capoor, K. and Ambrosi, P. 2006. *State and Trends of the Carbon Market*. IETA and The World Bank, Washington DC.
10. Ellis, J., Winkler, H., Corfee-Morlot, J. and Gagnon-Lebrun, F. 2007. CDM: taking stock and looking forward. *Energy Pol. 35*, 15–28.
11. Boyd, E., Hultman, N.E., Roberts, T., Corbera, E., Ebeling, J., Liverman, D.M., Brown, K., Tippmann, R., et al. 2007. *The Clean Development Mechanism: An Assessment of Current Practice and Future Approaches for Policy*. Tyndall Centre, Working Paper 49. Tyndall Centre on Climate Change, Norwich.
12. Brunt, C. and Knechtel, A. 2005. *Delivering Sustainable Development Benefits through the Clean Development Mechanism*. The Pembina Institute, Canada.
13. Olsen, K.H. 2005. *UNEP Riso Centre: Energy, Climate and Sustainable Development*. Riso National Laboratory, Roskilde, Denmark.
14. Hicks, R.L., Parks, B.C., Roberts, J.T. and Tierney, M.J. 2008. Greening Aid? Oxford University Press, Oxford.
15. Begg, K. and van der Horst, D. 2004. Preserving environmental integrity in standardized baselines: The role of additionality and uncertainty. *Mitigation Adapt. Strat. Glob. Change 9*, 181–200.
16. Kjellén, B., Egenhofer, C., van Schaik, L. and Cornland, D. 2005. *Improving the Clean Development Mechanism*. European Climate Platform, Gothenburg.
17. Corbera, E. and Brown, K. Building institutions to trade ecosystem services: Marketing forest carbon in Mexico. World Dev. (In Press).

Nathan E. Hultman
2101 Van Munching Hall
School of Public Policy
University of Maryland
College Park, MD 20742, USA
hultman@umd.edu

Emily Boyd
Environmental Change Institute
Oxford University Centre for the Environment
South Parks Road
Oxford OX1 3QY, UK
emily.boyd@ouce.ox.ac.uk

J. Timmons Roberts
Department of Sociology
College of William & Mary
P.O. Box 8795
Williamsburg, VA 23187, USA
jtrobe@wm.edu

John Cole
Environmental Change Institute
Oxford University Centre for the Environment
South Parks Road
Oxford OX1 3QY, UK
john@cole.ch

Esteve Corbera
Faculty of Social Sciences
School of Development Studies
University of East Anglia
Norwich NR4 7TJ, UK
e.corbera@uea.ac.uk

Johannes Ebeling
EcoSecurities, Ltd.
1st Floor, Park Central
40/41 Park End Street
Oxford OX1 1JD, UK
Johannes.Ebeling@ecosecurities.com

Katrina Brown
Faculty of Social Sciences
School of Development Studies
University of East Anglia
Norwich NR4 7TJ,
k.brown@uea.ac.uk

Diana M. Liverman
Environmental Change Institute
Oxford University Centre for the Environment
South Parks Road
Oxford OX1 3QY, UK
diana.liverman@eci.ox.ac.uk