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Best management practices for corporate, academic and governmental transfer of sustainable technologies to developing countries

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Abstract Innovations with respect to technologies that contribute to environmental sustainability have emerged within national government laboratories, international agencies and within academic research institutes. Since each of these entities is understandably more focused on ab initio research, conceptual development and proofs of concept, the production level manufacturing and broad dissemination of such technologies require development of best management practices (BMPs) for effective partnerships with and/or technology licensure to private sector industry. Alternatively, certain technologies that address specific environmental sustainability needs within the developing countries can be and have been transferred directly, either through bi-lateral transfers or through multi-lateral agencies, serving as intermediaries. The appropriateness of such transfers is contingent upon host country

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environmental, cultural and socio-political conditions, the type of technology involved, the "terms of transfer" and the relationships established between the technology conceivers and the end-users. The authors select examples of identified modes of sustainable technology transmission and derive experiential BMPs, which may be of some utility for future sustainable technology transfer. Moreover, in providing these BMPs, the historical record and contemporary caveats with respect to unregulated technology transfer, whether sustainable or otherwise, to developing countries and the array of corresponding proposed codes of conduct are examined, given the normative objective that such technologies should ultimately contribute to ecologically benign and societally beneficial objectives, such as environmental sustainability, equitable growth and poverty alleviation. These issues and the need to establish BMPs would be broadly relevant with the new focus on climate change-related technology funds and associated regional impact projects evolving across the globe and within the developing countries in particular.

Keywords Best management practices · Developing nations · Environmental sustainability · Climate investment fund · Globalization

Introduction

The countries of Africa, Asia and Latin America have endured invasion, exploitation, colonization and oppression in myriad forms throughout the centuries. Despite the thin patina of respectability provided by conceptual frameworks such as pacification, civilization, manifest destiny, protectorate establishment, civil order restoration, modernization and religious enlightenment, the "beneficiaries" of such largesse, all too frequently, paid the price for such benefits with the loss of their sovereignty, freedom, culture, language, land, natural resource entitlements and, in many instances, their lives. Since the collective memory of slavery, segregation, colonialism, apartheid, armed suppression and economic subjugation persists, there is little wonder that even benign technological offerings from the former colonial and neocolonial countries are often greeted with suspicion and resistance.

Indeed, the early transfers of such technology were anything but benign. Rather, they represented the means to more effectively and profitably extract natural resources and manpower for the benefit of the colonial power and later the corporate shareholders, rather than such benefits accruing to the indigenous populations. In the post-independence era, growing consumer demand combined with unregulated import policies, predatory corporate practices and, in certain instances, political corruption, led to numerous situations wherein technologies were introduced to multiple economic sectors that were ill suited to local environmental conditions, where spare parts were not available and training to produce skilled local operators was virtually nonexistent (Amin 1990).

In response to such abuses, the "appropriate technology" movement was initiated, which began to address the need for locally relevant and adapted technological advances for mechanized agriculture, household appliances, durable goods, regional commercial manufacturing, mining and civil infrastructure projects. The perspective was such that "intermediate technology" was needed until such time as host country infrastructure and skilled labor capacity were sufficient to advance toward state-of-the-science technology (Pursell 1993). In certain circumstances, however, "intermediate technology" in essence emerged as "terminal technology", because neither the capital for infrastructure upgrades nor the capacity building of the labor force materialized.

With the growth in global economies and the focus on sustainable resources for reducing the impact of climatic changes, a growing array of developing countries positioned themselves to deploy cutting edge technologies in the service of sustainable development. One such example is the approximately 6 billion USD pledged by the World Bank for Climate Investment Fund (CIF) for developing climate-resilient economies through Clean Technology Funds and Strategic Climate Funds. These new mechanisms for technology transfer pose an urgent need for reviewing and adopting best management practices (BMPs) for effective partnerships, and form the basis for this paper.

Foreign direct investment (FDI) in developing countries

In their enthusiasm to attract foreign investors, in the hope of stimulating economic growth, creating employment and establishing supply chain linkages with local businesses, countries throughout Asia, Africa and Latin America have offered an array of incentives to multinational corporations (MNCs). These have included reduced bureaucracy, tax holidays, relaxation on profit repatriation regulations, waiver of import duties for needed manufacturing inputs, exemption from environmental impact considerations, investment in infrastructure improvements and in specific workforce training (Kobrin 1999). Such incentives, while frequently successful with respect to the primary objective of luring foreign investors, did not routinely result in contributing to anticipated benefits to the host country. Corporate practices, such as transfer pricing, wherein excessive corporate home office administrative or consulting fees were charged to the subsidiary, eliminated profits upon which local taxes could be based, once the tax holidays had expired. In some cases

the MNCs such as Enron Corporation themselves ceased to exist due to financial turmoil, thus negating the potential for the longer term returns the host countries such as power projects in India expected for the initial investments and credits provided for the infrastructure projects. A World Bank report (Claessens et al. 2001) confirms that the profitability of banks is different in the developing and developed countries, FDIs and foreign banks generally become more profitable than domestic banks in developing countries. This increase in the market share of the foreign banks further erodes the profit makers for the domestic sectors. Other unintended consequences of unregulated FDI included a negative economic growth impact due to the volatility of FDI flows (Lensink and Morrissey 2006; Hermes and Lensink 2003), threats to national sovereignty (Kobrin 2003), non-homogeneity of impact across regions (Padilla 2008), exacerbated disparity among economic classes, environmental pollution and depletion of natural resources without a reasonable rate of return to the host country.

Attempts to regulate transnational corporate investment

The range of initiatives undertaken by host governments to control or regulate transnational corporate investment practices included development of codes of conduct (Baram 1994), formation of coalitions of countries to set conditions for investment, to outright expropriation, nationalization and indigenization of foreign industries (Wilson 1990; Kobrin 1984). During the anti-apartheid disinvestment campaign in South Africa, the Rev. Leon Sullivan posed a compromise under which companies who became signatories to his "Sullivan Principles" could continue to operate their enterprises in South Africa, arguing that it established a voluntary basis for non-discriminatory hiring and firing practices, elimination of child labor, worker harassment and corporal punishment, fair wages, intellectual property protection, equitable treatment of the workforce, occupational health and safety, right to unionization and commitment to environmental sustainability. Although the concept of such compromise to total disinvestment was understandably challenged at the time, these subsequently evolved into "The Global Sullivan Principles," which were since adopted by an array of businesses (http://www.globalsullivanprinciples.org/principles.htm).

The lack of enforceable requirements, however, still prompted both individual countries and groups of nations not to rely upon "voluntary" codes of corporate conduct, but rather to establish mandated pre-conditions for FDI and on-going monitoring of investment practices.

An early advocate of regulation of FDI was the coalition of countries that initially comprised the Andean Pact (i.e., Peru, Bolivia, Ecuador and Columbia) established in 1969 and known since 1996 as the *Comunidad Andina* (CAN) (http://www.comunidadandina.org/endex.htm). Venezuela was a member and other countries (i.e., Paraguay, Uruguay, Argentina, Chile and Brazil) later joined as associate members. The Pact members signed the Cartagena Agreement and advocated greater regional control over the "terms of trade" and introduced concepts such as "sunset clauses", under which foreign investors would have pre-stipulated limitations on the duration of their ownership of the means of production, as opposed to the assumption of business control in perpetuity. Other requirements called for inclusion of local joint venture partners, training of indigenous managers, limitations on expatriation of capital and an equitable share of profits. With specific reference to sustainability, the Andean Pact addressed common access to genetic resources in the preamble to Decision 391, as translated from the Spanish by the International Law Project of the Lewis and Clark Law School, Portland, Oregon:

> The Member Countries have sovereign rights over the use and exploitation of their resources, a principle which has furthermore been ratified by the Convention on Biological Diversity, signed in Rio de Janeiro in June 1992 and endorsed by the five Member States;
> The Member Countries have an important biological and genetic heritage which must be preserved and used in a sustainable manner;
> The Andean countries are by nature multi-ethnic and pluricultural;
> Biological diversity, genetic resources, endemism and rarity, as well as the knowledge, innovations and practices of indigenous, Afro-American and local communities in relation to these, are of strategic value at international level;
> It is necessary to recognize the historical contribution of indigenous, Afro-American and local communities to biological diversity, its conservation, development and the sustainable use of its components, as well as the benefits yielded by such contribution;
> That indigenous, Afro-American and local communities maintain a close interdependence with biological resources which must be strengthened in order to conserve biological diversity and promote the economic and social development of these communities and of the Member Countries;
> It is necessary to strengthen scientific, technical and cultural cooperation and integration, as well as the integral, harmonious development of the Member Countries;
> Genetic resources are of great economic value, since they are a primary source of products and processes for industry…" (http://www.lclark.edu/org/ielp/andeaneng.html).

Corporate and donor country responsibility

Periodic pressure by the developing countries, variously described as third world countries, "non-aligned", economic "periphery," underdeveloped or less developed countries (LDCs), has been directed toward both multinational corporations and toward the major highly industrialized nations, variously identified as the "the North", "the West", or the Group of Eight (G8) (http://g8-summit.town.toyako.hokkaido.jp/eng/index.html). The venues for such pressure included the 1976/77 North/South Dialogue, an 18-month summit held in Paris, between representatives of 21 rich and poor countries, entitled the Conference on International Economic Cooperation (CIEC), which ended without major accomplishments (Amuzegar 1976, 1977). Other vehicles for addressing the need for sustainable technology transfer between rich and poor countries have included the United Nations Conference on Trade and Development (UNCTAD), the General Agreements on Tariffs and Trade (GATT) (http://www.wto.org/english/tratop_e/gatt_e/gatt_e.htm), the United Nations Economic Commission for Africa (UNECA) (http://www.uneca.org/), the Manila Declaration of the International Conference on Conflict Resolution, Peace Building, Sustainable Development and Indigenous Peoples (http://www.twnside.org.sg/title/manila.htm), and the Third World Forum (http://www.forumtiersmonde.net/fren/index.php), inter alia. The World Bank Clean Technology Fund (CTF), in developing its guidelines, is currently proposing nine principles that center on its core mission of poverty reduction with sustainable economic growth for adapting or mitigating climate change via an open and transparent dialogue between banks, countries and the CTF (Clean Technology Fund 2008).

Sustainable appropriate technology transfer:

For deriving BMPs for some of the major categories engaged in transfer of sustainable technology, and an experiential assessment of past transfers and a proactive determination of both technological advances and future constraints, the authors developed a typology, hereinafter referred to as SATT (sustainable appropriate technology transfer). The intent is to identify and differentiate those criteria that have validity with respect to such transfers to developing economies, irrespective of the technology provider, as well as those BMPs that might be considered to be specific to technology transfers being conducted by corporate, governmental and academic providers, as follows:

GEN_SATT	sustainable appropriate technology transfer (SATT) that is "Generic" to all transferring entities
GOV_SATT-B	SATT provided through government to government (i.e., "bi-lateral) transfers, typically though through their aid agencies [e.g., United States Agency for International Development-USAID, (http://www.usaid.gov/) Gesellschaft für Technische Zusammenarbeit GTZ—The German Aid Agency (http://www.gtz.de/en/), Canadian International Development Agency (CIDA)] (http://www.acdi-cida.gc.ca/index-e.htm)
GOV_SATT-M	SATT provided by multi-lateral agencies (e.g., Agencies of the United Nations http://www.un.org/, NATO http://www.nato.int/, European Union (EU) http://europa.eu/, Arab Authority for Agric. Investment and Development (AAAID) http://www.aaaid.org/)
NGO_SATT	SATT provided by non-government organizations (NGOs) or by private voluntary organizations (PVOs) (e.g., International Red Cross; Red Crescent; Doctors Without Borders; Catholic Charities, John Snow, Inc.; Abt Associates; Management Sciences for Health; Marie Stopes Foundation; Clinton Foundation, Bill & Melinda Gates Foundation; Ford Foundation; Carter Foundation; Teamsters Union; Sierra Club; Greenpeace)
MNC_SATT	SATT provided by a multinational corporation or transnational corporation (e.g., IBM, SONY, Barclays Bank) or by a Parastatal corporation (e.g., OPEC, PEMEX, Glavcosmos)
UNIV_SATT	SATT provided by a University, College, Ministry of Education, Learned Professional Society, Accrediting Organization, Fraternity or Sorority

BMPs for transfer of sustainabe technology to less developed countries

The generic sustainable appropriate technology transfer (GEN_SATT) BMPs, inasmuch as they are applicable to Less Developed Countries (LDCs), without regard to the source of such transfers, must be broadly generalized and, ideally, derived from field implementations that have promising components. Caution is advised with respect to overly optimistic initiation of technology transfer implementations, given the complexity and unique characteristics of each sector

and the geopolitical environment (Harris and Tanner 2000), ranging from the international transfer of health information systems technology to Chad (Foltz 1993), energy technology to the Chinese automotive industry (Gallagher 2006), the electronics industry in Mexico (Padilla 2008), to the transfer of cleaner mining technologies to South America (Hilson 2000). One deterrent to technology transfer to the developing countries has been the concern over the adequacy of protection for intellectual property rights on the part of corporate IP owners; whereas, LDCs lament the potential impact of technology transfer on the displacement of indigenous industries (Maskus 2004).

Clearly, the agricultural sector has been the major beneficiary of both technology transfer and articulation of BMPs, as a consequence of the "green revolution". DeVuyst and Ipe (1999) attempted to delineate incentives to encourage adoption of agricultural BMPs. Related initiatives addressed BMP formulation with respect to a "pluri-disciplinary" approach to farming (Turpin et al. 2006), mariculture water management (Stanley 2000), farmer adoption of water quality management practices (Houston and Sun 1999; Cooper 1997), shrimp farming in Honduras (Engle and Valderrama 2004), and cattle farming (Obubuafo et al. 2006). Analogous contributions to the literature addressed sustainability in an array of sectors within the LDCs, including sustainable aquaculture (Boyd and Schmittou 1999; Quansah et al. 2007) and sustainable energy (Spaulding-Fecher and Mwakasonda 2005). The following specific implementations were selected as exemplars in each of the categories of transferring entities.

From government

Bi-lateral: USAID-FEWS

The United States Agency for International Development (USAID) developed the Famine Early Warning System (FEWS) in the late 1980s, in collaboration with Tulane University's School of Public Health and Tropical Medicine and NASA's Goddard Space Flight Center, to assist in efforts to monitor drought and identify the people most likely to be affected. FEWS was born out of the need observed in Ethiopia and the Sahel in 1970s and 1980s in which extreme drought caused severe famine. Information systems did not exist at that time to provide warning of the early stages of drought so that food aid emergency response by the international community could be provided to avoid famine. USAID used the existing NOAA and NASA satellite-based technology which had become available during 1980s to make earlier detection of drought. Since that time, satellites from many other countries have also been used for the early detection of drought. According to USAID, the Famine Early Warning Systems work best where government resources are focused on the areas at high risk for drought, flooding, crop failure or locust infestation. However, it has been observed that a lack of democracy, free press, and presence of armed conflict or endemic disease are some of the factors which pose serious food security threats, whether or not the areas are affected by drought and natural disasters. FEWS routinely provides timely notification to decision-makers; yet, there is often some latency in political and economic response time, notwithstanding early notification (http://www.usaid.gov/press/releases/2002/fs020826_2.html).

Multi-lateral: UN FAO–ARTEMIS and GIEWS

USAID FEWS Network (http://www.fews.net/Pages/default.aspx) continues to integrate remote sensing technology and socio-economic data in collaboration with local, regional and international partners so as to provide critical information for decision support related to food security in Africa, the Caribbean, Latin America and Asia. The United Nations Food and Agriculture Organization's (UN FAO) Africa Real-Time Environmental Monitoring Information System (ARTEMIS) has deployed NOAA's AVHRR and the European Space Agency's geostationary Meteosat data to determine areas in Africa that are at risk for desertification and for infestation by the desert locust *(Schistocerca gregaria)*. In a Somalian real time emergency report that provided insight into the level and effectiveness of the support provided through USAID and UNFAO, it was established that the systems provided adequate support and information that helped maximize efforts that saved the lives of millions (Grünewald 2006). In other such reports from around the African continent, it has been noted that surveillance and forecasting capabilities for the desert locust (Hielkema et al. 1990), provided by the ARTEMIS system, has allowed for the allocation and rationing of food and livestock resources as a precautionary measure during annual drought and harsh rainy seasons in some parts of Africa. The USAID and UNFAO have acquired substantial experience in early warning technology and the applications of remotely sensed images for drought, food crop monitoring, livestock emergency response and relief operations in Africa. However, the changing nature of the emergencies have made it imperative that these two organizations receive the additional necessary funding to adapt to the new problems of food insecurity and livestock shortages created by the increasing threat of weather related natural disasters and the associated regional impact of climate change.

In addition to the USAID and UNFAO's operation FEWS and ARTEMIS, respectively, the UNFAO also manages the Global Information and Early Warning

System (GIEWS) (http://www.fao.org/giews/ENGLISH/index.htm), which identifies five criteria for effective early warning: (1) Collection, thorough review, analysis and archiving of records relevant to food and livestock security. (2) Formation of a flexible system that can adapt to dynamic environmental and socio-economic conditions. (3) Establishment of inter-regional uniformity with respect to information format and content. (4) Management of information by deploying state-of-the-art equipment and associated software for monitoring and imaging purposes. (5) Installation of appropriate speed of communications for time-critical events.

The FAO Remote Sensing Centre and the NASA GSFC (Goddard Space Flight Center) developed ARTEMIS in collaboration with the University of Reading (UK) and the National Aerospace Laboratory of the Netherlands. ARTEMIS was effective because it included a 10-year vegetation index archived on a 10-day (decadal) and monthly basis, since August 1988 and offered on a routine basis for the continent of Africa and the Near East; monthly estimated rainfall maps for the Southern Sahara, the Sahel, Sudan, and the tropical countries of West Africa; and monthly composite vegetation index maps for Africa, and the Near East. This archive can be used for early assessment of crop growth conditions by comparing current trends with past experience (http://gcmd.nasa.gov/records/GCMD_CIESIN0122.html). Such climatology would not been possible with only on ground information and would have hindered the warning and effectiveness of the system. This is an example for the role of broadly available technology becoming an effective source of regional information with different agencies and countries providing the expertise.

International Disaster Charter

The International Charter aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each member agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property (http://www.disasterscharter.org).

The European and French space agencies (ESA and CNES) initiated the International Charter "Space and Major Disasters" following the UNISPACE III conference held in Vienna, Austria in July 1999. The Canadian Space Agency (CSA) signed the Charter in 2000. The International Charter was declared formally operational on 1 November 2000.

The description of the process to initiate a Charter request follows: an authorized user can call a single number to request the mobilization of the space and associated ground resources (i.e., RADARSAT, ERS, ENVISAT, SPOT, IRS, SAC-C, NOAA satellites, LANDSAT, ALOS, DMC satellites and others) of the member agencies to obtain data and information on a disaster occurrence. A 24-h on-duty operator receives the call, checks the identity of the requestor and verifies that the user request form sent by the authorized user is correctly filled up. The operator passes the information to an emergency on-call officer who analyzes the request and the scope of the disaster with the authorized user, and prepares an archive and acquisition plan using available space resources. Data acquisition and delivery take place on an emergency basis, and a Project Manager, who is qualified in data ordering, handling and application, assists the user throughout the process.

The current 19 member agencies in the Charter are given in Table 1.

Table 1 Current International Charter members

International Charter Members	Space resources
European Space Agency (ESA)	ERS, ENVISAT
Centre national d'études spatiales (CNES)	
Spotimage	SPOT
NSPO	Formosat
Canadian Space Agency (CSA)	RADARSAT
Indian Space Research Organization (ISRO)	IRS
National Oceanic and Atmospheric Administration (NOAA)	POES, GOES
Argentina's Comisión Nacional de Actividades Espaciales (CONAE)	SAC-C
Japan Aerospace Exploration Agency (JAXA)	ALOS
United States Geological Survey (USGS)	Landsat
Digital Globe	Quickbird
GeoEye	GeoEye-1
DMC International Imaging (DMC)	
Centre National des Techniques Spatiales (Algeria)	ALSAT-1
National Space Research and Development (Nigeria)	NigeriaSat
Tübitak-BILTEN (Turkey)	BILSAT-1
BNSC/Surrey Satellite Technology Limited (UK)	UK-DMC
BNSC/Qinetiq (UK)	TopSat
China National Space Administration (CNSA)	FY, SJ, ZY satellite series

Source: International Disaster Charter (http://www.disasterscharter.org)

NATO Science for Peace and Security (SPS): Science for Peace (SfP) Program

NATO's SPS represents the merger of the former NATO Committee on the Challenges to Modern Society (CCMS) and the NATO Science Committee (SCOM). "The SPS Committee is the primary NATO committee supporting

practical cooperation in civil science and innovation. This new organization oversees a program which contributes to NATO's mission by linking science to society through projects conducted under well-established procedures. It focuses on security, environmental sustainability and other defined priorities of its Partner nations. The SPS program enables NATO to "demonstrate its commitment to practical, visible projects with tangible output" (http://www.nato.int/science/index.html). Sampling only the NATO SPS grants involving Egypt during 2007, one can discern the breadth and depth of focus on transferring sustainable technologies through this multilateral mechanism (http://www.nato.int/science/studies_and_projects/country-reports/EGPYT.Cntry%20Update%202008.pdf). Funded projects include sustainable waste water management, real-time water quality warning and communication, chemo and biosensor systems for safeguarding and environmental control, development of alternative water resources in the Sinai, innovative processes for nitrogen removal, antimicrobial and hypoallergenic product development, viral pathogen detection techniques, organic/inorganic sensor hybrids and real-time remote sensing for early warning and mitigation of disasters and of epidemics through identification and monitoring infectious disease vector habitat (Zhou et al. 1998; Rochon 2005; Quansah et al. 2008). The latter project, the Kamal Ewida Earth Observatory, was initially awarded as a Planning Grant to a coalition involving Purdue University's Purdue Terrestrial Observatory, Boğaziçi University's Kandilli Observatory and Earthquake Research Institute and two host universities in Egypt, Cairo University in Giza, Egypt and Al Azhar University in Nasr City, Egypt. The ground-stations in Egypt have strong support and collaboration from the government ministries and affiliated departments within each of the universities. In addition to the primary disaster mitigation function, the facility will have enormous interdisciplinary research and instructional impact, given that Cairo University, which celebrated its centennial anniversary in 2008, has an enrollment of 200,000 students and Al Azhar University, founded in 988 A.D. has an enrollment of 500,000 students (Rochon et al. 2009).

From private sector corporations

Examples of NGO's/non-profit corporations

Engineers Without Borders International (http://www.ewb-international.org/)

Engineers Without Borders (EWB) is a humanitarian organization which provides assistance such as application of sustainable engineering projects (e.g., water filtration systems, village electricity generation, alternatives to slash and burn agriculture, rice drying mechanisms, heat powered LED lighting, low-cost portable lighting, crop residue removal, vegetable oil extraction machines, solar and wind powered mango dryers, cold weather composting), training internationally responsible engineers and engineering students to provide appropriate engineering services and consultations for developing communities. Their EWB-USA affiliate (http://www.ewb-usa.org/) has chapters on university campuses, major municipalities (http://www.ewbnewyork.com/index.php), within government laboratories and with various engineering firms.

Médecins Sans Frontières

Doctors Without Borders/Médecins Sans Frontières (MSF) is an international medical humanitarian organization made up of 19 associative organizations around the world and created by doctors and journalists in France in 1971. MSF provides assistance for about 60 countries to people whose survival is threatened by violence, neglect or catastrophe, primarily due to armed conflict, epidemics, malnutrition, exclusion from health care or vulnerability to natural disasters (http://www.doctorswithoutborders.org/).

Seeds of Hope Outreach (SOHO) (http://www.seedsofhopeoutreach.com/)

Seeds of Hope Outreach (SOHO), founded by Cynthia Prime of Indianapolis, Indiana, is a "501 C3 non-profit, faith-based humanitarian organization dedicated to relieving suffering and bringing hope to orphans, vulnerable children (OVCs), women at risk and the destitute elderly in communities hard hit by HIV/AIDS, through sustainable programs that improve their quality of life and help equip them for a brighter future. SOHO collaborates with a diverse group of organizations, academic institutions, business entities and churches to address hunger, illiteracy, health care and HIV/AIDS prevention, economic empowerment and spiritual nurture, emphasizing a holistic approach and programs that foster self reliance." SOHO has initiated an array of programs in Swaziland, Lesotho and South Africa, combining food security, education, public health, technical expert consultation, welcome centers and local economic sustainability, through broadly based collaboration with community and tribal leaders, the medical and educational communities, and political elite, all focused on sustaining and improving the lives of vulnerable children and their elderly caregivers.

COSUAM de Puerto Rico (Corporación para la Sustenabilidad Ambiental) San Juan, Puerto Rico

Although COSUAM is still relatively in its infancy as an official organization, it has a vision of the role that an

enterprising non-profit organization can play in contributing to sustainable development, public health and environmental sustainability in Puerto Rico. COSUAM's objective is to emerge as an advocate for culturally sensitive, humane economic growth that is mindful of ecosystem conservation, energy efficiency and poverty alleviation.

In its inaugural year of operation, COSUAM has assessed the impact of commercialization on residential neighborhoods, jointly sponsored alternative energy initiatives in collaboration with a manufacturing cooperative, developed promotional educative materials addressing the organization's goals and capabilities and presented such in print, electronic and radio media. COSUAM is positioned to serve as model for combining professional consultancy, grass roots advocacy, public health education and environmental conservation on the path to equitable and sustainable economic development (http://cosuam.org/index.htm).

Multinational corporations

Spatio-temporal epidemiological modeler (STEM)

The STEM application has built-in Geographical Information System (GIS) data for multiple countries. It incorporates data about country borders, populations, shared borders (neighbors), interstate highways, state highways and airports. STEM is designed to make it easy for developers and researchers to plug in their own models. It comes with spatiotemporal susceptible/infectious/recovered (SIR) and susceptible/exposed/infectious/recovered (SEIR) models pre-coded with both deterministic and stochastic engines. The parameters in any model are specified in XML configuration files. Users can easily change the weight or significance of various disease vectors. Users can also create their own unique vectors for disease transmission. STEM websource and download information is provided at the STEM Eclipse Setup webpage (http://wiki.eclipse.org/index.php/STEM_Eclipse_Setup). STEM was developed by IBM and subsequently freely provided to the open source community (http://www-03.ibm.com/press/us/en/pressrelease/21656.wss).

"The spatiotemporal epidemiological modeler" (STEM) tool is designed to help scientists and public health officials create and use spatial and temporal models of emerging infectious diseases. These models could aid in understanding and potentially preventing the spread of such diseases. Policy makers responsible for creating strategies to contain diseases and prevent epidemics need accurate understanding of disease dynamics and the likely outcomes of preventive actions. In an increasingly connected world with extremely efficient global transportation links, the vectors of infection can be quite complex. STEM facilitates the development of advanced mathematical models, the creation of flexible models involving multiple populations and interactions between diseases, and a better understanding of epidemiology".

In addition to placing the STEM software tool in the public domain, IBM has recently installed the only two known civilian supercomputers in Africa. Both are IBM Blue Genes, one located at the National Authority for Remote Sensing and Space Sciences (NARSS) in Cairo, Egypt, and the other at the Center for High Performance Computing (CHCP) in Cape Town, South Africa. The two research facilities are now developing collaborations to address selected sustainable development initiatives impacting the continent of Africa. Additionally, IBM has installed the first two Cloud Computing Centers outside the industrialized West, one in Pretoria, South Africa and the other in China and has installed a high performance data center for Telecom Egypt. The potential for harnessing such combined computational capability, in the service of HIV/AIDS vaccine research, tropical disease mitigation, disaster vulnerability assessment, environmental impact studies and poverty alleviation in Africa, represents a major departure from the usual set of grand challenge projects typically engaging supercomputer centers on the top 500 list.

BMPs from academic institutions

In addition to incorporating sustainable production theory and applications within their curricula (Rochon et al. 2006), academic institutions engage in both formal technology transfer through spin-offs or start-ups, research joint ventures and licensure agreements (Clarysse 2007), as well as through "informal technology transfer", defined as being either commercial technology transfer, industrial consulting or joint publications with industry scientists (Link et al. 2007). Alternatively, as in the case of the MultiSpec exemplar from Purdue University, the transfer went directly to the global end-users, without partnering with either private sector firms or government agencies. By providing an open source product to the public domain, with free internet downloads, help desk and regular updates, a loyal, diverse and grateful clientele emerged. In contrast, the Cytometry for Life (C4L) T cell counter for HIV/AIDS testing represented a Hybrid, what Elmuti et al. (2005) refer to as a strategic alliance between universities and corporations, in that a faculty from Purdue University collaborated with a company to prototype the low-cost, battery-operated device for subsequent use in rural Africa.

Purdue University: MultiSpec

Commercial software for the analysis of remote sensing images can be expensive for users in developing countries.

However, there are some free to low cost alternatives that even though they do not provide all of the capability available in commercial packages, they do provide the key features needed for training. One of these applications is MultiSpec (Biehl and Landgrebe 2002) that is under continual development at Purdue University. MultiSpec is a software application for analyzing image data from aircraft and satellite-borne multispectral and hyperspectral sensors such as LANDSAT TM, SPOT, MODIS, IKONOS, EO-1 Hyperion, AVIRIS and many others. MultiSpec is implemented for personal computers running the Apple Macintosh operating system (OS) and the Microsoft Windows OS.

The BMPs guiding the MultiSpec design are

- The implementation should be on a readily available personal computer platform which has adequate processing power, but is financially within the reach of any Earth science user.
- The system should be easy to learn and easy to use, even for the infrequent user, using the most modern of software environments.
- The system should provide for easy import of data in a variety of formats, and easy export of results, both in thematic map and in tabular form.

MultiSpec had its origin in the LARSYS multispectral image analysis system (Phillips 1973), which was one of the first remote sensing multispectral data processing systems, originally created during the 1960s. A number of the systems in government laboratories, university research labs, and several commercially offered products are descendants of this system.

The original purpose for the development of MultiSpec was to provide an easy to use tool that could be used for teaching, research, but especially, to provide the ability for researchers to try new techniques without having to program the algorithms. It is used in graduate level remote sensing courses to teach signal processing analysis techniques. Graduate students use it to take advantage of algorithms developed by previous students as they develop and study new algorithms.

MultiSpec has the capability to effectively deal with a large number of spectral bands (of the order of 100–200 or more) of future sensor systems and a large number of classes (of the order of 50 or more). The current version of MultiSpec has been used for displaying and analyzing data sets of more than 200 spectral bands.

An unexpected outcome of the MultiSpec effort is that a substantial number of requests for MultiSpec came from teachers of the K-12 level. MultiSpec has been used in K-12 programs such as the Gaia-Crossroads Program in Maine and the GLOBE Program (http://www.globe.gov/) (Ryan 2003).

The package has been copyrighted to protect against misuse, but it is freely distributed to requesters via the internet at: http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/. Currently, more than 1,500 copies are known to be downloaded each year to users in over 80 countries representing universities, government, commercial and K-12 institutions. The MultiSpec distribution breakdown in 2007 by organization type is given in Table 2.

Table 2 Known MultiSpec download breakdown for 2007 by organizational type

Organizational type	Number of downloads
Commercial	74
Government	145
K-12 Schools	38
University	650
Not known	688

Source: Landgrebe (2008)

Purdue University: Cytometry for Life (C4L)

CD4 T cell testing for HIV/AIDS in rural Africa: the Purdue C4L initiative

The C4L initiative centers on the need for affordable, reliable and manageable CD4 T-lymphocyte cell testing in Africa. The aim for the C4L initiative is to create a low cost, low maintenance, portable CD4 Counter that will test, and only test, the amount of CD4 T-lymphocyte cells in humans efficiently and accurately. Many of the flow cytometers that are currently in use are large, expensive. They require trained technicians, and numerous resources to operate and maintain them. The components used to effectively accommodate bulky cytometers are scarce in most of Africa, which translates into the majority of the HIV/AIDS-infected population not receiving critical testing that would result in treatment that would be life-prolonging (Willyard 2007; Robinson et al. 2008).

The current model for CD4 testing in Africa for the past 7–8 years is to create central labs that house expensive, mostly automated equipment, and train technicians to operate the machines and its complex software. Samples are taken from all over Africa to be tested in central labs and then sent back to the remote areas from which the samples came. The patient must therefore spend a great deal waiting due to the lengthy process of receiving the results. This model is based on the philosophy of Western health care systems, which rely on heavy infrastructure and centralized networks; only the main populated cites in Africa can assimilate this model. The downfalls of using the centralized model is that it forces the people in the rural parts of Africa to travel from their homes to the central labs to receive testing, which thereby make CD4 testing exclusive to large cites and areas that support the infrastructure. Also, since CD4 testing is high in demand, the

central lab systems become overloaded, due to frequent testing, therefore creating a need for more system automation (Willyard 2007; Robinson et al. 2008).

The low cost, low maintenance, portable CD4 counter with full optical and fluidic assembly will be housed in a high impact plastic, and contain powerful electronic components that are user friendly, and will need no computer attachments or additional software and/or interfaces. The CD4 counter will also include GPS capabilities, cell phone based data transmission, battery operation, CD4 T cell single line readout, and a gravity-feed low-volume sheath fluid system. These features will allow the CD4 counter to become very robust and durable thus having the capability to adapt to any situation that may present itself in Africa. With the addition of GPS, other than the ability to track the portable devices, the CD4 Counter will have the ability to transmit epidemiological data; this feature can provide vital information on the geographical regions of Africa with higher incidence of HIV/AIDS and of antiretroviral resistant strains of HIV/AIDS and facilitating prompt and accurate decisions with respect to HIV therapy distribution to highly infected areas (Willyard 2007).

Harvard University: The Harvard Institute for International Development (HIID)

The Harvard Institute for International Development (HIID) (1974–2000) (http://www.cid.harvard.edu/archive/hiid/index.html) maintained a strong partnership with developing countries, focused on the development of polices to accelerate their sustainable economic growth and improvement of human welfare.

The international development programs pursued by HIID in a wide range of activities are regularly reported in HIID's series of Development Discussion Papers. The development topics include agriculture and food policy, education, economic reform, sustainable environment (e.g., Kuo and Shukla 2000; Rosengard et al. 2000; Snyder et al. 2000; Boscolo et al. 2001). In June 2000, HIID was dissolved and its functions were integrated into schools within the University, in order to institutionalize the development work that has historically been carried out by HIID, linking it more closely with the teaching and research of Harvard University.

Tuskegee University

Tuskegee University (formerly Tuskegee Institute) was founded in 1880 by an act of the Alabama State Legislature, as the Normal School for Colored Teachers. The university has a long history of agricultural extension and technology transfer, including wide dissemination of information on over 300 products derived from peanuts and over 100 derived from sweet potatoes, all developed by its most distinguished professor, Dr. George Washington Carver (1864–1943). Although many historical Black Colleges and Universities now engage in sustainable technology transfer, especially with their counterpart institutions in Africa, Tuskegee University, through its Office of International Programs (OIP), has long collaborated with developing countries and research institutes. It has provided technical assistance in order to develop an effective and responsive international program that aims at affecting human resource development, economic policy changes, institutional development and technology transfer through the design and implementation of projects. The OIP is currently partnering with 18 institutions in 13 countries (including 10 in Africa) to provide various forms of humanitarian and agricultural resources. An important milestone of this program was a workshop on "Rural Development and Economic Performance in Africa", held on April 2001 in Atlanta (Georgia). The Tuskegee Workshop convened 47 policymakers and academics to review the status of agricultural and rural development in Africa, identify priority interventions, and make recommendations to the sixth African–African American Summit and to the Partnership to Cut Hunger in Africa.

Conclusions and recommendations

Many of the safeguards that developing countries attempted to impose on FDI since the 1960s to the present time have direct relevance to formulating contemporary BMPs, that are now applicable the transfer of sustainable technology to developing countries. Moreover, the review of the current literature, personal experience with collaborators from Africa, Asia, Latin America and the Caribbean, provided opportunities to observe the different facets of transfer, facilitated by the identification of exemplar SATT strategies. The different modes of SATT available have various legacies and parameters to consider that can work in individual setups. Clearly some of the basic attributes such as sustainability, integrated involvement of all the partners associated with the transfer, and demonstration of success or challenges are common to the different SATTs. Yet for each situation and technology transfer instance an appropriate model or models would need to be integrated and modified. It has also been clarified, as articulated by Ruffing (1999) that technology transfer is but one of the means, one tool set for achieving sustainability and thereby necessitating a collateral emphasis on education, cooperative agreements, taxes and tradable permits, assessment of environmental costs, negotiation of policy instruments, as well as vitally important informed decision-making.

A fundamental need exists to evaluate and verify the efficacy, functionality and appropriateness of sustainable technologies, ideally prior to mass manufacturing and field deployment. The model developed by the US Environmental Protection Agency (US EPA) for verification of environmental technologies (http://www.epa.gov/etv/) could potentially be adapted to address the need to certify the utility, suitability for operation within specific developing country conditions and longer term technological sustainability. Accordingly, an initiation of an SETV (Sustainable Environmental Technology Verification) Program, targeted to ensuring and facilitating optimal transfer, operations and management of sustainable technologies to developing countries should be explored. This is particularly timely as climate change, energy alternatives, environmental sustainability, and public health for poverty alleviation become integrated in future SATT programs.

Finally, when confronting the enormity of the ongoing and future challenges related to HIV/AIDS crisis and climate change, the persistence of vector-borne infectious diseases, the pervasiveness of poverty and the frequency of famine, drought, biogenic and anthropogenic disasters, it is incumbent upon the international community, irrespective of corporate, academic or governmental affiliation, to urgently address remediation of these crises as a primary objective. It is insufficient for modest mitigation of human suffering to simply be a by-product of corporate wealth accumulation through technology marketing, of governments' focused political alliances or of academic recruitment and research collaboration.

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