Natural Pozzolans for Sustainable Development:

Mapping Poverty in the Philippines

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Abstract

Alleviating poverty and reducing environmental pollution in less developed countries are important goals of sustainable development. Lower building costs and reduced pollution should make development more sustainable. Most often, concrete is made with Portland cement, produced in developed countries. Byproducts of Portland cement production are carbon dioxide and particulate matter, environmental pollutants that harm human health. Natural Pozzolans are substitutes for Portland cement that include: diatomaceous earth, volcanic ash, and rice husk ash. We consider technology transfer from the United States of America to the Philippines. North America is more developed than is Southeast Asia and thereby provides a model for technology transfer in less developed parts of the world. We use Geographic Information Systems to map cement resources, safe drinking water, sanitary toilet facilities, and makeshift housing. Regions where poverty is prevalent and natural pozzolans are available can be targeted to develop more sustainable construction.

I. The Problem

Concrete is a common building material consisting of water, sand, gravel (i.e. aggregate), and cement. Portland cement is the most prevalent cementing material in the world. The negative external byproducts of Portland cement production include carbon dioxide and particulate matter. These airborne toxins pollute the environment by producing acid rain and harm human health by causing lung disease. The third-party costs of externalities in the form of environmental degradation from cement production constitute market failure and present a global problem. Market failure is a conventional rationale for government intervention in the marketplace with corrective instruments, such as public policies. We discuss environmental regulation of the cement industry under environmental protection.

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A potential solution to the problems of cement production is an environmentally friendly concrete technology that uses naturally occurring pozzolans to extend Portland cement. This “green” concrete technology could lower building costs and reduce environmental degradation, thereby making the cement industry become more sustainable worldwide.

Potential benefits of concrete sustainability include: improved water sanitation, increased natural and human capital, affordable housing, and reduced pollution from carbon dioxide and particulate matter.

There is evidence that cement production is cartelized in the Philippines. Cartels often increase consumer prices by reducing the supply of goods or services (i.e. cement) to make extra profits. Aldaba (2000) reports evidence of price collusion among cement producers in the Philippines. Cartelization of the cement industry is also a market failure. We discuss economic regulation of the cement industry under sustainable development.

An international collective action problem exists where developed countries have externalized costs of environmental pollution and natural resource depletion on the world, but insist that less developed countries not take the same path for their own development. Less developed countries may be willing to take a different development path, but expect technical assistance as fair compensation. Here, we consider the prospects for a transfer of viable concrete technology from the United States to the Philippines. The Philippines was formerly a commonwealth country under the United States. North America is more economically developed than is Southeast Asia and it should provide a global model for technology transfer. Technology adoption must be considered, not only technically but also socially, because engineering is bounded by social context. Different channels for technology transfer were considered for natural pozzolans (see Berry & Berry, 1999).

Technology transfer from the United States of America to the Philippines should enable the natural pozzolans solution to be politically viable and economically efficient. Spatial analysis, using geographic information systems models, was conducted to show how natural pozzolans technology can become part of a life cycle in cement production. Natural pozzolans are a renewable resource, which means they are strongly sustainable.

II. Theory

Reducing environmental pollution and alleviating poverty in less developed countries are important goals of sustainable development. The Bruntland Report (World Commission on Environment and Development, 1987) first coined the term sustainable development to mean: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development falls into three domains: environmental, economic, and social.

In the environmental domain, we posit a technical solution to a global problem with cement production that could reduce environmental degradation. In the economic domain, we propose substitute ingredients for making cement, i.e. natural pozzolans; that fits into existent life cycles for volcanic deposits and the byproducts of rice consumption. We might conserve natural capital and create social capital simultaneously when we can reduce both environmental degradation and poverty with lower cost cement. Is there a market for "green" concrete? If so, then will social institutions allow green concrete to be utilized? Such thinking may indeed be out-of-the-box green design considerations.

While solutions to problems may be possible from an engineering perspective, they might not necessarily be feasible or viable in a social context. Inefficiency may result where markets dominate social values and fail to provide solutions to problems. Globalization might exacerbate problems where international trade ignores boundaries, territories, and sovereignty (see Choucri, 1999). Hence, international trade in cement is regulated only indirectly by host countries for industry. World governing bodies exist, but they often lack teeth in policy instruments necessary to enforce market conditions, which could reduce externalities.

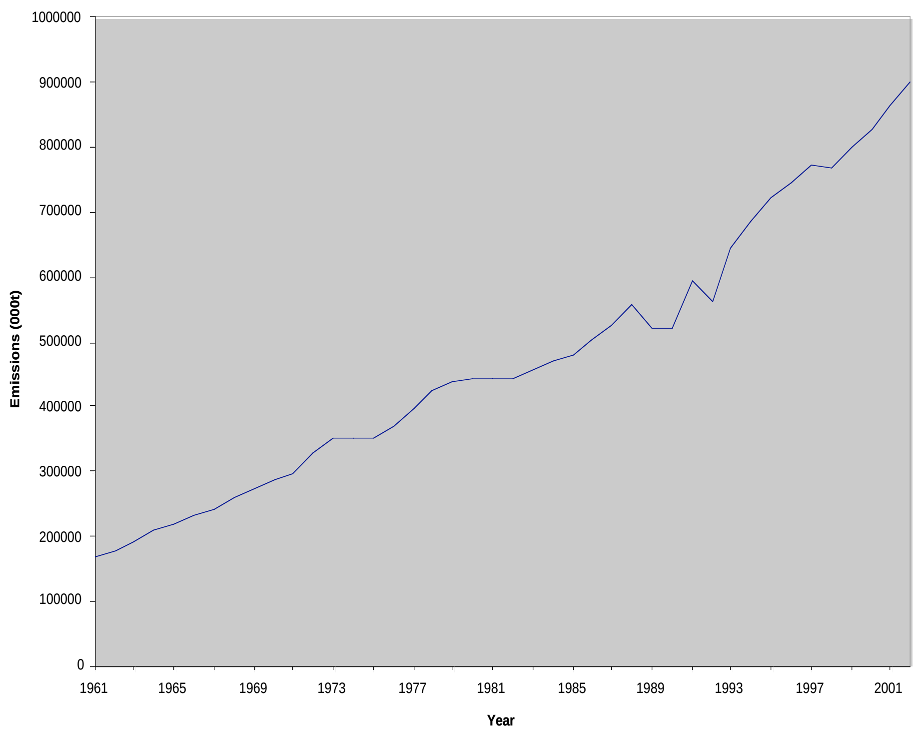
Ecological economics (Costanza, 1996) differs from neoclassical economics by taking into consideration the nature of nonrenewable substitutes. Weak sustainability is where land (natural resources), labor, and capital are all substitutable with utility theory (Gowdy, 1999). Strong sustainability holds that nonrenewable resources should not be exhausted, but should instead be recognized as a form of natural capital. Goodland and Daly (1996) distinguish between growth and development when defining sustainability. Natural pozzolans provide development without growth or value-added development.

In sections below, we discuss the cement industry in relation to environmental protection, sustainable development, and technology transfer. We apply these concepts to international trade in cement, namely between the United States and the Philippines.

II.A. Environmental Protection

When framing Agenda 21, participating countries under the United Nations made policy prescriptions connecting sustainable development with environmental protection (United Nations Development Programme, 1994). Although the United States cement industry is regulated by the US Environmental Protection Agency, the United Nations has neither jurisdiction nor enforcement authority over US cement firms. Figure 1 shows rising global carbon dioxide emissions (measured in thousand metric tons), due to increasing cement production over the last forty years (Hanle, et al., 2004). To the extent that cement production is unregulated in the global marketplace, a common pool problem may exist (see Hardin, 1968) in which cement producers lack selective incentives to limit negative externalities (harmful byproducts), like carbon dioxide and particulate matter. Nevertheless, evidence of voluntary action by cement producers (Holcim, 2005) shows promise for Agenda 21. Voluntarism is discussed below in the applications section under technology transfer.

Figure 1. Carbon Dioxide Emissions from Hydraulic Cement Production, World (1961-2002)



Source: U.S. Geological Survey Open-File Report 01-006. 2004. Historical Statistics for Mineral and Material Commodities in the United States. <http://minerals.usgs.gov/minerals/pubs/of01-006/#data>

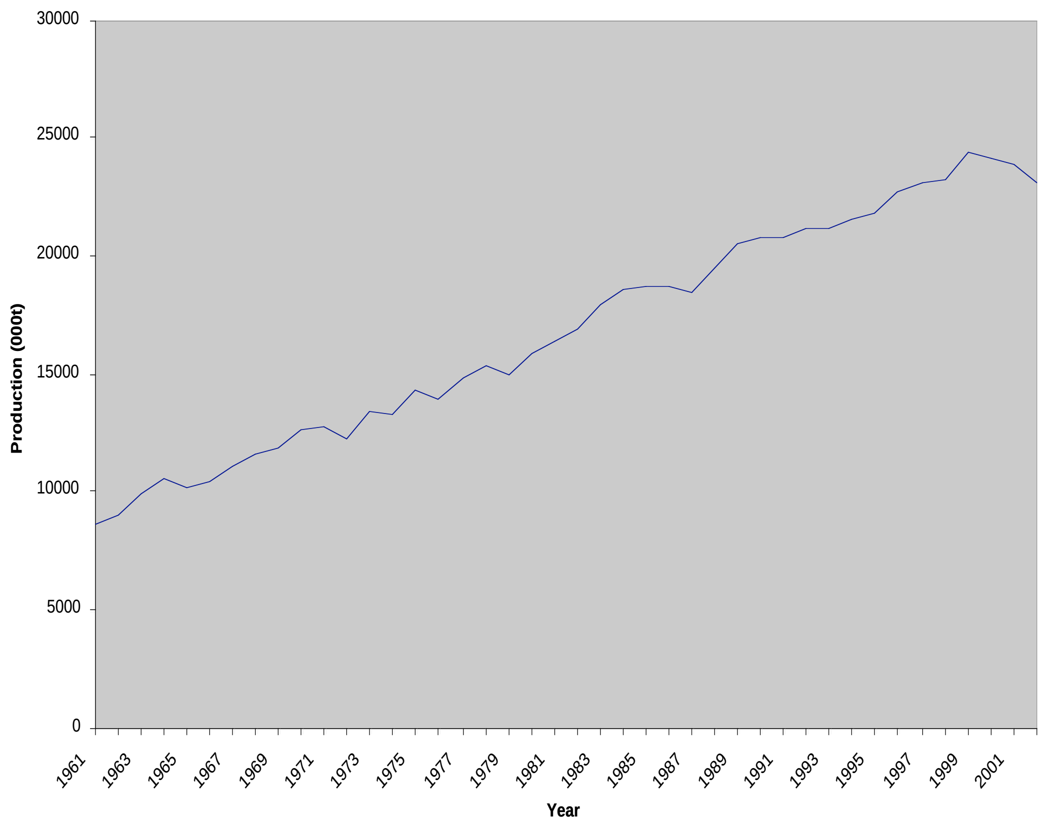
In 2002, 1.8 billion metric tons of hydraulic cement was produced worldwide, with the vast majority being Portland cement. This global production has contributed to 5% of the total global industrial energy consumption and anthropogenic CO_2 emissions. In addition to CO_2 emissions, cement production is a significant emitter of SO_x, NO_x, particulate matter, and other pollutants. Cement production contributes to the harmful effects of global warming, overuse of minerals, and nonrenewable resource depletion. Regionally, acid rain, water contamination by spills, and stream sedimentation occur from cement manufacture. Local cement production contributes to noise, vibrations, chemical contaminations, scenic ecological degradation, and various health problems.

II.B. Sustainable Development

The social context of sustainable development is viewed as a constraint set for possible solutions to problems offered by technology. Sustainability often refers to a whole class of problems requiring collective action (Olson, 1965). Collective action problems, such as market failures, may be fixed with selective incentives in appropriate circumstances. What selective incentives can we provide for cement producers to change their behavior? Natural pozzolans are alternative materials that substitute for Portland cement and do not require importation into less developed countries. This helps reduce the cost of cement, because natural pozzolans are locally available. Natural pozzolans include diatomaceous earth, volcanic ash, and rice husk ash, which are substitutes in ratios for Portland cement. Figure 2 shows the rise in rice husk ash production worldwide, over the last forty years. This rise is directly associated with an increase in population consuming rice as a staple.

Pozzolans are cementitious materials that extend Portland cement in the concrete mixture. Pozzolan comes from an Italian word pozzolana meaning "earth of Pozzuoli," which is a city by Naples. When hydrating Portland cement, pozzolans chemically react with calcium hydroxide to form calcium silicate hydrates. Calcium silicate hydrates are strong binders that harden the concrete. Manufactured byproducts, such as fly ash and blast furnace slag, are used by the cement industry as substitute ingredients in making Portland cement. However, natural pozzolans, including rice husk ash, diatomaceous earth, and volcanic ash, are seldom utilized when making Portland cement nowadays.

Figure 2. World Rice Husk Ash Production (1961-2002)



Source: IRRI (International Rice Research Institute). 2002. World Rice Statistics. Manila (Philippines): IRRI <www.irri.org/science/ricestat/>

The use of natural pozzolans for hydraulic cement began in prehistoric times when early Egyptians used lime mortars in pyramids. The Romans later used pozzolan technology to create magnificent structures, such as the Colosseum which stands today. The technology was abandoned for over one thousand years before being used again in 18th C. England, but was abandoned for Western-based Portland cement technology by the early 1900's. Portland cement manufacturing involves burning powdered coal and natural gas, a production process which emits carbon dioxide gas into the atmosphere.

The feasibility of substituting these natural pozzolans was evaluated using six criteria. These criterion included availability, strength, workability, implementation, environmental impact, and economics. All three natural pozzolans were found to have widespread distribution on several continents around the world. Compressive strength tests indicated that volcanic ash and rice husk ash could be safely substituted for Portland cement up to 25%, and diatomaceous earth up to 6.25%. Because of its porous structure, as determined by scanning electron microscopy, diatomaceous earth was found to require a lot of water addition, decreasing its likelihood to be implemented on a construction site in the developing world. Higher substitutions were deemed feasible for diatomaceous earth in the presence of super-plasticizing agents as had been reported in the literature; however, this method would not be appropriate for application in the developing world.

Testing shows that 25% of Portland cement can be safely substituted by natural pozzolans to create a concrete with similar strength (Anderson, et al., 2004). Though the rice husk ash samples were found to be stiffer than the volcanic ash, both were judged to be easily implemented for use in community-based infrastructure systems. Test results suggest rice husk ash and volcanic ash are more cost effective than diatomaceous earth.

The construction industry is one of the top consumers of natural resources. The use of natural pozzolans is one aspect of green building that can make a difference in the construction industry. The impacts of green building by using natural pozzolans can be better understood by utilizing the three categories described below. Undoubtedly, the most noticeable benefits to green building are the environmental hazards avoided by using green products. The use of natural pozzolans will inevitably decrease the amount of CO_2 released into the air during the processing of Portland cement. Currently around 30% of greenhouse gas emissions are produced from the building industry. Furthermore, during the processing of raw materials into Portland cement there is a significant amount of waste that is created. As a partial replacement for Portland cement, the use of natural pozzolans will reduce the amount of raw materials that are required. Natural pozzolans will in turn reduce and reuse pre-existing natural waste produced from the environment. The building industry accounts for 40% of all raw materials used worldwide (Nordberg, 2004). The use of natural pozzolans should contribute to the reduction of raw materials used by the construction industry. By using natural pozzolans, nonrenewable resources can be saved, including rock containing calcium (i.e. limestone and calcium carbonate).

Green building can also reduce the operating cost for producing green materials. Portland cement is often too expensive for people living in less developed countries, such as the Philippines. Cement alternatives offer reduction in material costs of construction. Natural pozzolans would be an economic benefit to citizens building new infrastructure. The economic benefits of using natural pozzolans could save contractors up to 25% per bag of cement. Savings would allow the communities to build more infrastructures, such as sanitation facilities. Using natural pozzolans would save money for consumers, but the reduction of Portland cement could in turn reduce the profits of cement producers. However, the cement producers could prepare the natural pozzolans for purchase. This would allow plants to recover the economic loss from producing less Portland cement. By using natural pozzolans, the local standard of living may increase. The atmosphere will be cleaner by reducing NO_x and SO_x (smog) produced by cement refinement. The use of natural pozzolans should provide villages and cities with a better quality of life.

II.C. Technology Transfer

In the emerging global economy, an international consensus has developed that countries should become sustainable. This means we must minimize the production of greenhouse gases, for example. It seems both natural and imperative that innovations in technology and policy should be shared among developed and developing countries. Innovations in policy or technology need implementation. Countries and ”organizations of greater size and with greater levels of slack resources are assumed to be more innovative than smaller organizations and those with fewer resources” (Berry & Berry, 1999:180). Given that most research and development occurs in the developed countries, there is a predominant and indisputable tendency for technology export or policy transfer from more developed countries to less developed countries. Richer economies are more adaptive and tolerant of change and thus more likely to adopt new policies and technologies (Walker, 1969).

The role that governments play in support of technology diffusion is central to the emulation process. The World Bank adopted a strategy that incorporates environmental concerns into decisions on funding to underdeveloped recipient countries. In 2001, the World Bank stated its goal “to promote environmental improvements as a fundamental element of development and poverty reduction strategies and actions" (World Bank, 2001). Subsidies to developing countries from organizations like the World Bank and International Monetary Fund (IMF) are often conditional on policies promised by the recipient countries. Such "world-wide scrutiny" has diminished sovereignty of states, thereby furthering the globalization or internationalization of economies and policies.

The major role of the government in developing countries is creating knowledge at home and providing support to domestic agents of production (Singh, 2004:227). The United Nations Development Programme (UNDP) has led in identifying the knowledge gaps between more developed and less developed countries. The UNDP sees knowledge as a global public good, proclaiming a role for the international community in reducing knowledge gaps (UNDP, 2001; Stiglitz, 1999). "A major role of the state in developing countries is to provide a policy framework that will enable domestic agents of production to capture the spillover benefits created by the globalization of capital and technology" (Singh, 2004:227).

The UNDP defines "capacity building" as the "sum of efforts needed to nurture, enhance and use the skills of people and institutions to progress towards sustainable development" (UNDP, 1994). This is human capital formation. Importing technology to extend Portland cement should increase local ownership and development of resources, influence public policies to ensure efficient resource use, and enable nations or regions to improve their economies using natural pozzolans. As natural pozzolan use increases, human capital is formed, while limiting negative externalities from cement production.

In developing countries, construction accounts for much of the capital formation and is usually second only to agriculture as a source of employment (Nordberg, 2004).

Since government policies set the economic and legislative context in which industries operate, government policies could set an agenda that strives to implement sustainability. If the cement companies were to recover economic losses incurred from producing less Portland cement by creating a natural pozzolan market, it could benefit local purchasers of construction services. This approach may also thwart price collusion in the cement industry. In furthering capacity building, the subsidizing of a beneficial industry could assist in educating workers in skills necessary for pozzolan harvest, preparation and use. This government action, for a certain amount of time, would take the financial burden of technical training and the onus of innovation shift off of the cement corporations. In this way, public policies and actions serve to enhance the construction sector, as opposed to simply regulating it. If governments were to further recognize that public works projects that used pozzolan-extended cement were not only less expensive but also boosted local economies, there would be a positive feedback loop for the economic and social sectors.

Although government policies have mitigated many problems with environmental degradation, these efforts could be more effectively supplemented with voluntary efforts from corporations (Shrivastava, 1995). Private enterprise can play a key role transferring natural pozzolan technology to developing countries. Infrastructure investment, such as housing and water sanitation, would support health and education to better form human capital. Influencing multinational corporations to adopt innovative process technologies could drive infrastructure investment into areas targeted by public policies. For example, to reduce makeshift housing. Infrastructure development in turn supports both education and health institutions, adding to the formation of human capital in developing countries.

III. Application

Sustainable development may be viewed as three overlapping domains: environmental, economic, and social (Goodland & Daly, 1996). Development within this conceptual framework means change without growth. In this sense, substitution of a key ingredient for making concrete, i.e., by using natural pozzolans, is change without growth. What is essential for sustainability is internalization of social costs. Portland cement production generates socially undesirable byproducts, including greenhouse gases, which degrade the global environment and particulate matter, which harms human health. The negative externalities above are third-party effects. That is, neither consumers nor producers will consider the socially undesirable effect of byproducts, when producing Portland cement.

III.A. Environmental Protection

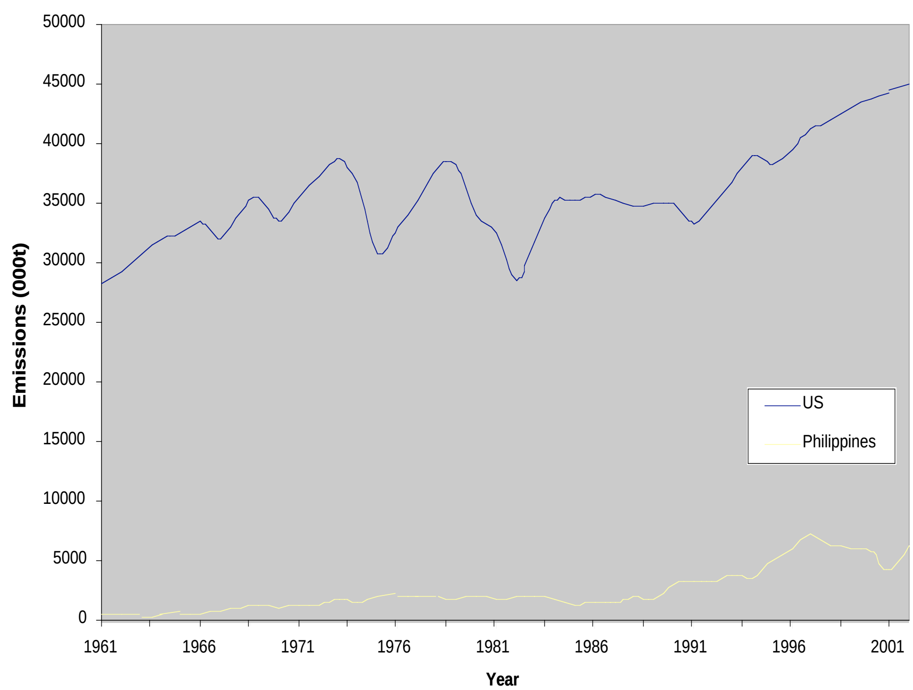
Externalities are classic "market failures" in economic parlance, meaning that individuals acting rationally will not change their behavior, even when they are made worse off as groups. This is justification for social (i.e. government) intervention in the marketplace, such as making public policy. While policy instruments might fix negative externalities, we must choose the best solution, even when that includes doing nothing. For example, "government failure" can make society worse off with marketplace intervention, where social costs exceed policy benefits. There is often a deadweight loss from intervention.

Figure 3 shows the rise in carbon dioxide emissions from cement production in the United States and Philippines, over the last forty years. Both countries are adding to the global problem with carbon dioxide emissions mentioned previously (see Figure 1). There is a direct relationship between cement production and carbon dioxide emissions.

Although the Environmental Protection Agency regulates the cement industry under the Clean Air Act, as amended, similar control of the Philippine cement industry is dubious.

The Philippine Clean Air Act of 1999 established the basic air quality policies in the Philippines (Republic of the Philippines, 1999). The Department of Environment and Natural Resources (DENR) has promulgated guidelines governing voluntary participation in pollution management appraisals in its relationship with the United States (Republic of the Philippines, 1993). While the Philippine Clear Air Act says "polluters must pay," the Industrial Environmental Management Project (IEMP) currently implemented by DENR

Figure 3.United States and Philippines CO2 Emissions from Hydraulic Cement Production (1961-2002)



Source: U.S. Geological Survey Open-File Report 01-006. 2004. Historical Statistics for Mineral and Material Commodities in the United States.
<http://minerals.usgs.gov/minerals/pubs/of01-006/#data>
Philippines Data graciously provided upon request by Hendrick van Oss of the U.S.G.S.
*Based on .5 tons CO2/ton cement

is designed “to encourage sustained industrial growth while improving environmental quality through reduced industrial pollution.” The approach includes a moratorium on compliance to effluents and emission standards. This is known as weak sustainability, because economic growth is targeted by government development policies, rather than minimizing environmental externalities, such as carbon dioxide and particulate matter.

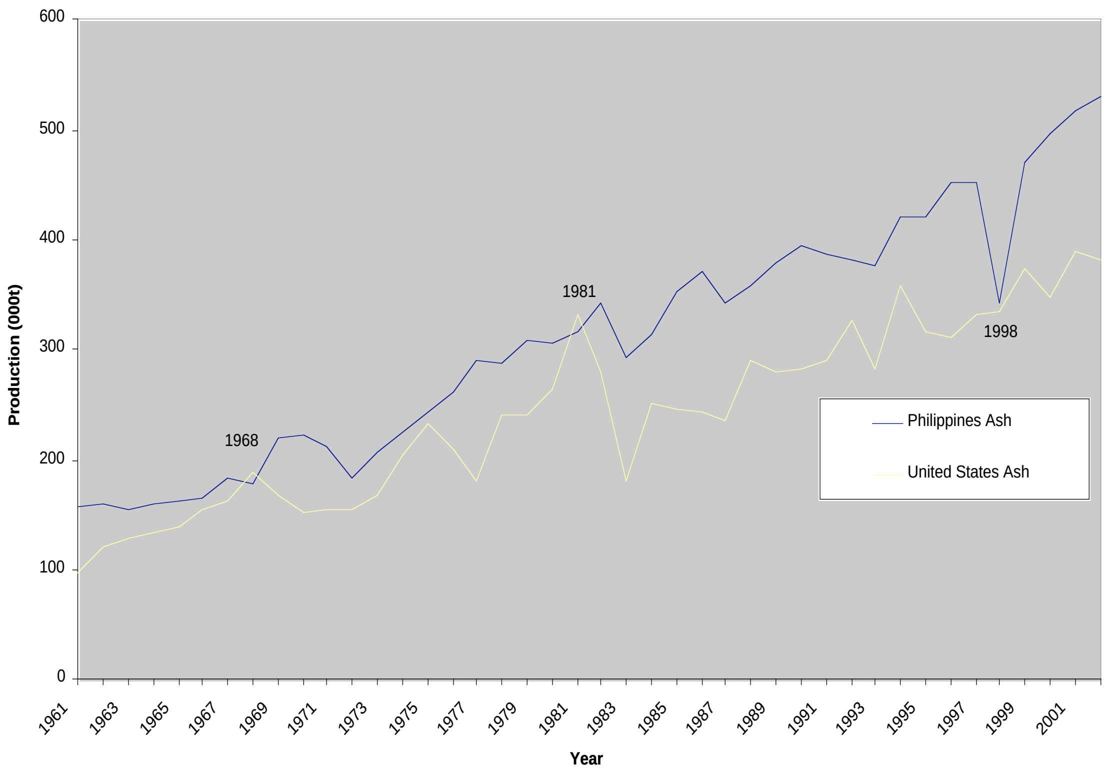
The Philippine cement industry is under economic regulation, as administered by the Philippine Cement Industry Authority (Aldaba, 2000). In the United States, cement producers are subject to economic regulation by the Federal Trade Commission and the Antitrust Division of the Department of Justice. These regulatory agencies do not have international trade authority. The bilateral trade relationship between the United States and Philippines is excluded. Moreover, US firms control the Philippine cement market, which could induce them to move production offshore, should regulatory costs increase.

III.B. Sustainable Development

The Philippines is one of several developing countries where an abundance of volcanic ash and rice husk ash can be found. Figure 4 shows the increase in rice husk ash in the United States and Philippines over four decades. Occasionally, more rice is produced in the Philippines than in the United States, shown where the lines cross in Figure 4. There is a direct relationship between rice production and rice husk ash as a byproduct and the availability of this natural pozzolan. The basic food staple for most Filipinos is rice, a commodity which when burned during the agricultural life cycle, yields rice husk ash. Rice husk ash and volcanic ash are renewable resources. There is minimal need for the governmental allocation of such resources, thereby allowing public policy to focus more on the implementation of pozzolan innovation and pollution abatement. We now turn to the industrial organization of the cement industry in the United States and Philippines.

In 2002, the United States produced 91,226,000 metric tons of cement, while the Philippines produced 9,000,000 metric tons of cement, adding to the total amount of 1.8 billion metric tons of cement produced worldwide. The bilateral trade relationship with cement production means net Philippine exports for consumption in the United States.

Figure 4. Rice Husk Ash in the United States and Philippines (1961-2002)



Source: IRRI (International Rice Research Institute). 2002. World Rice Statistics. Manila (Philippines) <IRRI www.irri.org/science/ricestat/>

Lafarge, Holcim, and CEMEX are respectively the first, second, and third ranked cement producers in the United States. Lafarge, Holcim, and CEMEX produced 40% of total clinker tonnage in 2001. Lafarge is the largest cement producer in North America.

Lafarge employs 15,500 people at 1,000 North American locations, including Canada. With 20 manufacturing sites in North America, 12 in the U.S., Lafarge produces 14.2 million tons of cement per year. In comparison, Holcim ships 15 million tons of cement per year and collects annual revenues of $1.1 billion. Holcim's 14 manufacturing sites and 70 distribution terminals employ 2,400 employees in the United States. Likewise, CEMEX employs 5,000 people at 12 manufacturing plants across the US. CEMEX is capable of producing 14.2 million metric tons of cement per year in the United States.

The Philippines' cement industry is comprised of 20 manufacturing sites that are dominated by three United States cement firms: Lafarge, Holcim, and CEMEX. Along with Blue Circle, these producers controlled 90% of the cement industry market share in 1999. For example, Holcim Philippines, Inc. produces 8.7 million metric tons of cement annually and employs 1,400 people across the Philippines. The second largest cement producer is CEMEX Philippines, which produces 5.8 million metric tons per year.

As US subsidiaries, these cement companies could pose problems for voluntary technology transfer, adoption, and regulatory compliance, because of their bargaining power in the international trade relationship between the United States and Philippines. They can thwart public policies in both countries that reduce potential profit margins.

The Philippine Department of Trade and Industry (DTI) plays a significant role in economic regulation of the cement industry. In 1998, cement imports were 1.5% of total market share. Cement imports from Taiwan increased 1,700% from 27,800 tons in 1999 to 472,400 tons in 2000. Taiwan captured 72% of total cement imports, by competing against Japan and Indonesia. By 2001, cement imports comprised 22% of the market share and the Philippine cement industry claimed losses of $280 million in 2000 and

$106.5 million in 1999. Six plants and 15 product lines were forced to close, an equivalent of 18% of the total market along with 4,000 jobs. Industry representatives claimed that the loss was due to unfair competition caused by foreign dumping of cement. The industry called the DTI's attention to the Anti-Dumping Act of 1999 and the Safeguard Measure Law which protected domestic companies from foreign surges. Importers from Taiwan claimed that its refusal to participate in cartel activity was the underlying issue. In November of 2004, the DTI issued a Cease and Desist order to Solid Cement Corporation, a member of the CEMEX family, for not meeting quality standards which caused the plant to shutdown.

The Philippine Institute for Development Studies (Aldaba, 2000) looked at tacit price collusion in the Philippine cement industry. Cement firms had increased prices by similar amounts during periods when supply, capacity, and depressed demand were low due to low construction industry trends. Price collusion betrays expected competitive behavior in free markets. Prices should have been cut during this period, with surplus cement growing by 6.5 million tons between 1997 and 1999. Industry representatives claimed that price uniformity was due to increased production prices and energy prices, but researchers have pinpointed historical price coordination. Collusion seems easy to manage, due to the small number of firms in the industry. Moreover, a trade association called the Cement Manufacturers' Association of the Philippines provides competitors with price and quantity data to help them coordinate prices. This market behavior can decrease the potential for natural pozzolans to affect cement prices without government intervention, such as international trade policy reform to increase domestic competition.

Like so many developing countries, the Philippines requires investment in water sanitation and housing infrastructure. Because poor people largely depend on physical labor for income, health conditions and education opportunities play an important role in poverty and income distribution (Gerson, 1998). Poor living conditions adversely affect the growth on human capital formation. The 20th C. has witnessed large flows of people moving from rural to urban areas. Manila, the capital and largest city in the Philippines, serves as an example of an urban region that has attracted large numbers of immigrants from rural areas in pursuit of better jobs that are unavailable in rural regions.

Manila cannot support the full employment demand, even for educated workers. There are thousands of people without income and basic necessities. Some people are forced into makeshift housing, housing made of scrap materials, often under extremely poor conditions. Reports estimate the number of makeshift housing units in Manila at one-half million. These houses do not allow for proper sanitation, plumbing for clean water, or electricity for energy demands. The health problems, education impediments, crime, and unstable poor living conditions create very unattractive investment climates.

A similar threat to human capital formation potential exists in rural areas of the Philippines. Two-thirds of people in rural areas of the Philippines lack access to potable water. This is higher than the Asian average of one in three people making water supply and sanitation facilities in rural areas a priority of the Philippine government. Low cost spring boxes or gravity fed water systems created from natural pozzolans could greatly aid in the government’s efforts. This development would be environmentally friendly as well. Providing safe drinking water supply to rural areas via concrete structures would contribute to the health status of the countryside and to human capital development by increasing the number of able-bodied workers. Since much of the country's agricultural industry is based in rural areas, this could boost production in this sector of the economy.

Including Holcim, ten international companies who participated in the Cement Sustainability Initiative (World Business Council for Sustainable Development, 2002), have developed this agenda for action:

> (1) Prepare for a more sustainable future by making more efficient use of natural resources and energy and engaging with local issues in emerging markets; (2) Meet the expectations of stakeholders and maintain their "license to operate" in communities across the world through greater transparency of operations, effective engagement with society, and initiating actions which lead to sustained positive changes; and (3) Individually understand and build new market opportunities through process innovations which achieve greater resource/ energy efficiency and long-term cost savings; product and service innovations to reduce environmental impacts; and work with other industries on novel uses of by-product and waste materials in cement production.

Corporate policies for Holcim and CEMEX cement manufacturers appear to be proactive in the remediation of harmful environmental effects associated with cement production. This is useful for natural pozzolan technology transfer because producers are generally easier to organize for collective action than consumers, primarily because of their lower organizational costs and secondarily because of their economic influence (Olson, 1965; Lindblom, 1977). If businesses accept natural pozzolan process technology as feasible and, better yet viable, the potential for strong sustainable development in the Philippines could improve, at least in terms of cleaner cement production and greener construction.

Holcim (2005) sees sustainable development as a business goal and established a policy based on three pillars: environmental, economic and social sustainability. In 2002, Holcim made the commitment to reduce global CO_2 emissions by 20% by the year 2010. The company plans to employ techniques including substitution of clinker with suitable mineral components, improving energy efficiency, substituting fossil fuels with biomass and waste materials, and reducing cement kiln dust disposal. Holcim has sustainability goals like building infrastructure for livable communities and community development.

We calculated the quantity of rice husk ash necessary to extend Portland cement in the United States and Philippines by 25%, which meets the technical requirements for strength testing of concrete under laboratory conditions. Worldwide and United States estimates reveal unmet demand for the rice husk ash required, but the quantity of rice husk ash available in the Philippines could extend Portland cement without increasing agricultural production. Furthermore, the Philippines has volcanic ash to be utilized for concrete. We have initiated mapping activities to locate natural pozzolans worldwide.

III.C. Technology Transfer

Technology drives a wedge between economic activity and environmental damage with (1) human capital formation, (2) technological transfer, and (3) direct poverty alleviation (Goodland & Daly, 1996). Accompanying public policy and/or technology transfer are necessary investments in education, training, and skills. Organizations with agendas that merge technological advances with the knowledge of policy diffusion models are useful for sustainable development. For example, Michigan Technological University sponsors students abroad for research experience, in engineering fields, to implement sustainable development technology solutions (see Anderson et al., 2004).

For ecological economics, we need to distinguish between feasible technology and viable technology for the environment, because according to Gowdy (1999:168):

> A technology that draws down irreplaceable stocks, or generates irreducible pollution, or violates the ability of funds to provide assimilative and restorative services, is not viable.

A viable technology is capable of maintaining the corresponding material structure that supports its resource flows and sustaining functions. Natural pozzolans are viable since they are renewable resources linked to the agricultural life cycle—growing rice for food.

In the American and Philippine social systems, where corporations are privately owned, governmental regulation mechanisms are external. In these systems, it is widely held that the state should intrude as little as possible in the activities of private actors in correcting market failures. However, it is in the best interest of both the industrial and social sectors for the government to assist them in capacity building. Capacity building involves institutional, organizational, and cultural systems. Restrictions in these systems thwart progress and can limit innovations brought by technology transfer. It is within the goals of a progressive developing government to allow accessibility to global knowledge and to explore new ways of creative economic implementation. Because most research is conducted in developed countries, it behooves the governments of developing countries to have an open-door policy that permits information influx into its country.

Such information influx can be transmitted via a variety of actors: international agencies, trade associations, research sectors, voluntary importation by companies, and the Internet. As the benefits of innovation become apparent, a natural support system works to create opportunities for realization. For example, the government may choose to support research, create incentives to adopt pozzolan innovation, and seek alliances that promote industry growth, thus emerging into an international pozzolan market.

Training courses, sponsored by agencies such as the World Bank, the IMF, the World Resources Institute, UNDP, etc., could be set up in locations that are proximal to natural pozzolan deposits. These deposit locations would be sites for future industries built around a pozzolan cement industry, thereby further increasing local employment. Some funding would cover overhead costs, while the remainder would fund outreach efforts within those countries and the training of pozzolan use in cement production.

The Organization for Economic Cooperation and Development reviewed human capital formation and foreign direct investment (Miyamoto, 2003). Research indicates that human capital formation is necessary for developing countries to fully benefit from foreign direct investment. Intensive investment in human capital alone is not sufficient for developing countries to benefit from foreign direct investment. Basic requirements include sound public policies and attractive investment climates, coordination between formal education and training programs, collaboration among key stakeholders, human resource development, and identification of enterprises that will benefit host countries.

III.D. Mapping Poverty

Mapping cement resources and poverty indicators in the Philippines has environmental, economic, and social benefits. The information displayed in layered maps (Figures 5-7) includes the geospatial distribution of rice-producing areas, locations of active volcanoes, cement plant sites, and areas in need of infrastructural development as indicated by a lack of potable water, improved sanitation, and prevalence of makeshift housing (Appendix). When these layers are integrated into a single map overlay, they provide an overview of the natural pozzolans (volcanic ash, rice husk ash) and their proximities to cement plants.

By holding cement resource layers constant over three poverty indicators, these maps serve as a tool in determining how one parameter affects another. For example, in each figure, cement resources such as volcanoes, rice production, and cement plants are displayed and used as a control. In Figure 5 safe drinking water is overlaid by province to visually evaluate the spatial relationships. Figures 6 and 7 similarly overlay sanitary toilet facilities and makeshift housing, respectively. Policy analysts and decision makers can utilize these poverty maps to allocate resources and transfer technology to mitigate environmental pollution from Portland cement production and help to alleviate poverty.

This GIS-based map overview can provide economic opportunities on several fronts. As rice husk ash and volcanic ash are natural byproducts, potential markets for pozzolan collection, preparation and transport to existing cement plants can be actualized. Philippine entrepreneurs could capitalize on this economic innovation. Rice farmers can likewise share in this profit, which is a net gain by receiving returns from rice processors who would now recognize rice husk ash as a commodity and not a disposable byproduct.

Many cement plants in the Philippines are located near major population centers where a decrease in particulate matter can help reduce the incidence of lung disease and related illnesses. Reducing environmental pollution is an integral element of sustainable development. Poverty mapping serves to connect the geographically referenced spatial data to non-spatial data. This allows geospatial attributes such as proximity and spatial distribution to assist in policy making, in resource collection, and in land use planning.

If government incentives support such capacity-building, not only can an advent in technological transfer jumpstart a cement industry that is purposively pozzolan-based, but also cement plants could be constructed near natural pozzolan centers. In addition, the emergence of locally-owned natural pozzolan centers and cement plants may lessen collusion efforts of the large cement companies. All these scenarios are consistent with sustainable development. The GIS map serves as a visual aid for entrepreneurs to both recognize these avenues for economic sustainable growth, and to determine feasibility.

The social benefits of natural pozzolan usage can also be more easily understood by poverty mapping. GIS is very useful in identifying poverty zones. Areas in general need of improved potable water, sanitation facilities, and adequate housing can be seen with a glance. These areas, especially if located near cement plants, could benefit from using less costly cement for infrastructure construction, including homes, schools, roads, and community centers. More sustainable construction materials, i.e. natural pozzolans, may be used to alleviate poverty and reduce environmental pollution, while improving economic opportunities for growth in ancillary industries as part of the rice production life cycle. As rice is produced and consumed as a staple, rice husk is burned as a fuel; rice husk ash yields a natural pozzolan, which closes the loop on poverty and pollution.

IV. Conclusion

Technology can drive a wedge between economic activity and environmental damage through human capital formation, technological transfer, and direct poverty alleviation (Goodland & Daly, 1996). Transferring the natural pozzolan technology should help to reduce environmental pollution created in cement production and create human capital.

The direct relationship between cement production and carbon dioxide emissions means that reducing cement production with the substitution of natural pozzolans could simultaneously reduce environmental degradation and lower construction costs in less developed countries. There is a direct relationship between rice production, especially for local consumption, and rice husk ash made available. Rice husk ash is a proven safe substitute or extender for Portland cement. Using natural pozzolans, which are a free or low cost good, we hope to reduce cement-making costs by up to 25%, saving funds for building needed structures in the developing world and reducing pollution worldwide.

Technology transfer to the Philippines contributes to environmental, economic, and social sustainability in the form of poverty alleviation and human capital formation. Infrastructure development with spring box and gravity fed water systems constructed from natural pozzolans offers an affordable and environmentally friendly solution to the problems of potable water, sanitation, and makeshift housing. Improvement in poverty conditions increases the potential of health and education gains, which in turn builds a stronger workforce and attractive climates for investment. Initiatives in this direction may be driven by social policies such as those in the Aquino and Ramos administrations whose primary strategy for improving socioeconomic conditions in communities was to help people to upgrade themselves. This public policy proved to be cheaper than using contractors under design standards. While natural pozzolans may provide incentives to developing regions, technology transfers are more theoretically attractive than practical.

Our study began with the naïve notion that we could transfer viable technology from a developed country to a less developed country, thereby benefiting human society. Less developed countries may be exporting more Portland cement to developed countries than they consume domestically. Developed countries are “paving paradise,” so to speak. They build more with Portland cement than anywhere else, which means our focus may be misdirected towards less developed countries. Pozzolan substitutes are already in the cement ingredients of developed countries, but they are seldom natural in origin or tied with a renewable resource such as rice production. Locally available pozzolans should decrease the price of construction materials, and be processed using minimal training.

IV.A. Limitations of the Study

We assumed for analysis of technology transfer and adoption that natural pozzolans are free goods. No extraction costs, storage costs, or transportation costs were considered in this study for technological change to occur in cement industries, regardless of country.

IV.B. Directions for Future Research

We want to know critical distances between natural pozzolans, cement plant locations, and population centers with problems, such as water sanitation and makeshift housing.

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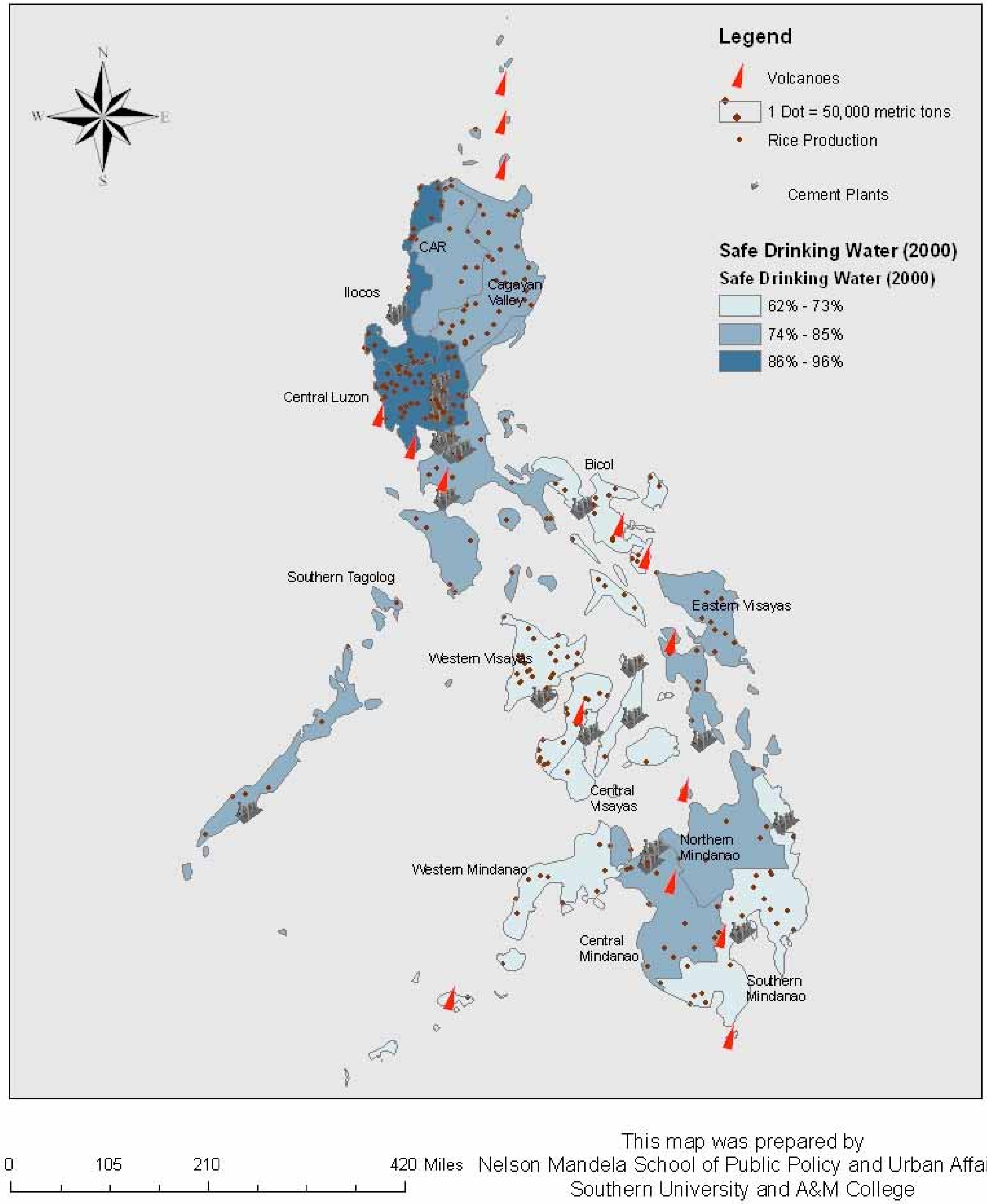
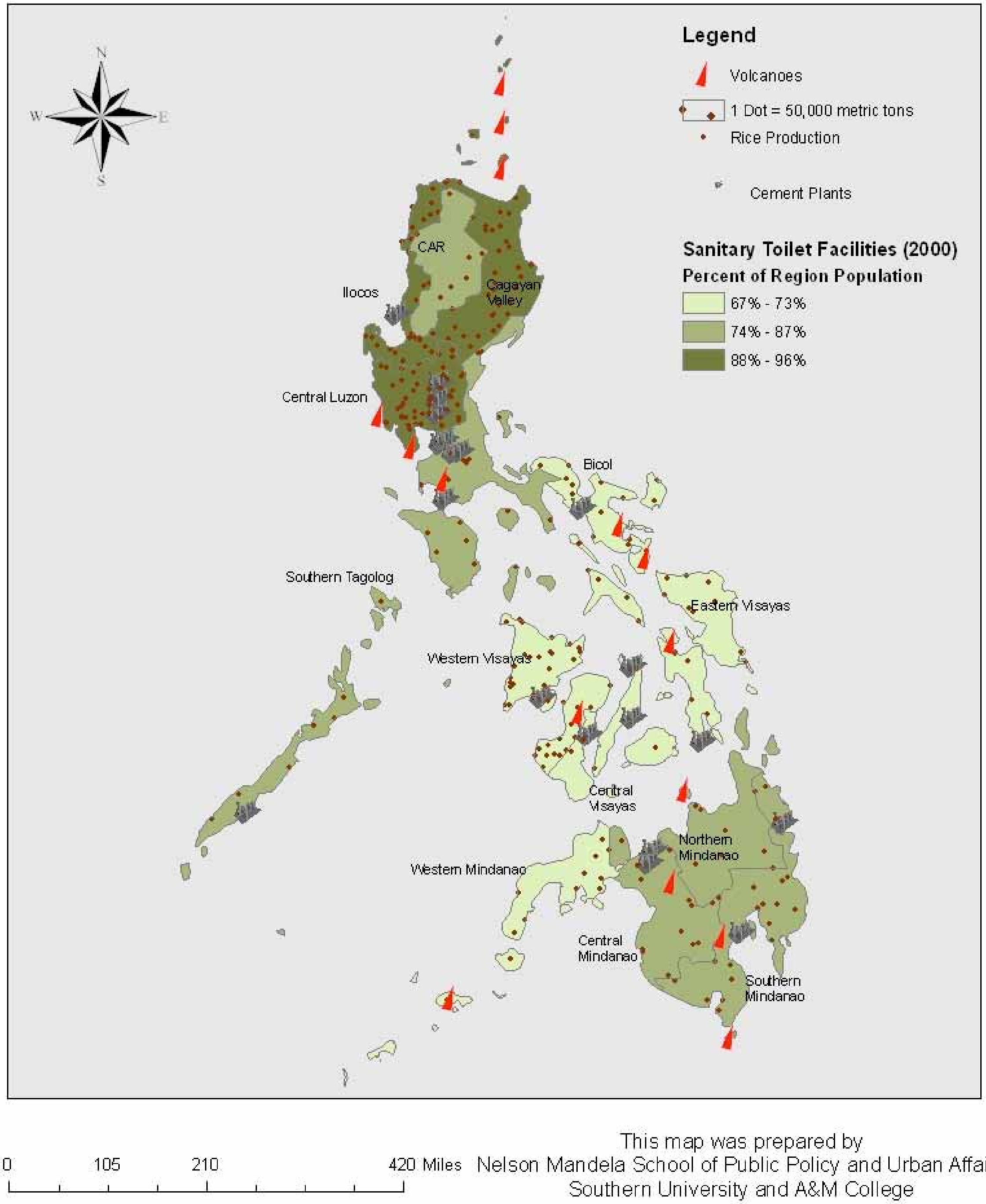
Appendix

Figure 5. Philippines Cement Resources and Safe Drinking Water



This map was prepared by
Nelson Mandela School of Public Policy and Urban Affairs
Southern University and A&M College

Figure 6. Philippines Cement Resources and Sanitary Toilet Facilities



This map was prepared by
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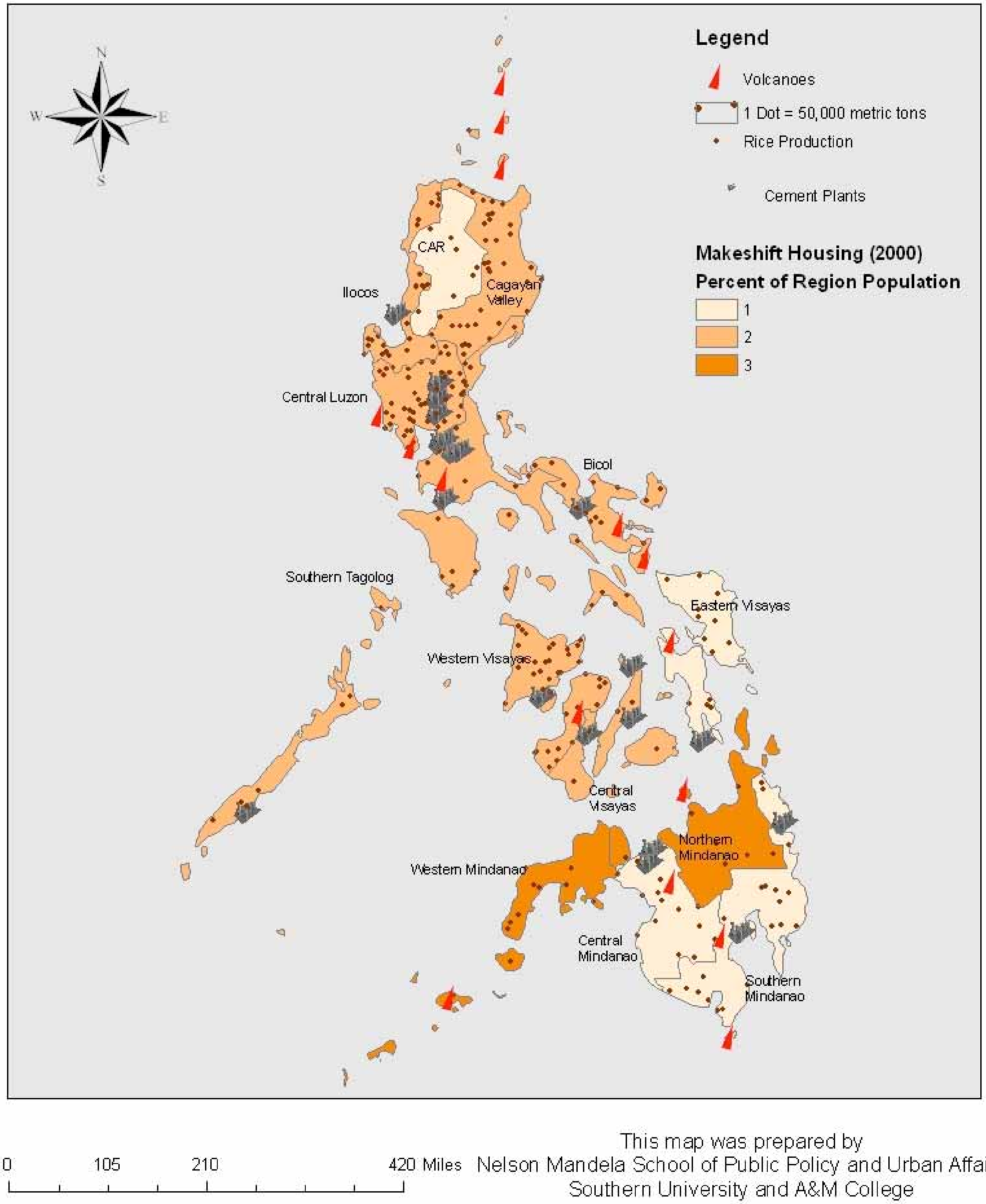
Southern University and A&M College

Figure 7. Philippines Cement Resources and Makeshift Housing



This map was prepared by
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