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Where is the Poverty–Environment Nexus? Evidence from Cambodia, Lao PDR, and Vietnam

SUSMITA DASGUPTA, UWE DEICHMANN, CRAIG MEISNER and DAVID WHEELER *
The World Bank, Washington, DC, USA

Summary. — This paper investigates the poverty–environment nexus at the provincial and district levels in Cambodia, Lao PDR, and Vietnam. The analysis focuses on spatial associations between poverty populations and five environmental problems: deforestation, fragile soils, indoor air pollution, contaminated water, and outdoor air pollution. The results suggest that the nexus is quite different in each country. We conclude that the nexus concept can provide a useful catalyst for country-specific work, but not a general formula for program design. Joint implementation of poverty and environment strategies may be cost effective for some environmental problems, but independent implementation may be preferable in many cases as well.

Key words — poverty, pollution, basic needs, deforestation, sanitation, natural resources

1. INTRODUCTION

During the past few years, the publications of international development agencies have highlighted the importance of the "poverty–environment nexus," a set of mutually reinforcing links between poverty and environmental damage (Bojö *et al.*, 2001; Bosch, Hommann, Rubio, Sadoff, & Travers, 2001; Ekbom & Bojö, 1999). In this nexus, poverty reduction and environmental protection are complementary goals. For environmentalists, the nexus concept has provided a welcome defense against arguments, based on the "Environmental Kuznets Curve," that the early stages of development are unavoidably marked by conflicts between poverty reduction and environmental protection. [1] Common profession of belief in the nexus has also smoothed uneasy relations between environmental specialists and traditional project officers in development aid organizations.

Numerous studies have suggested that environmental damage can have particular significance for the poor. Recent participatory poverty assessments, conducted in 14 developing countries of Asia, Africa, and Latin America, reveal a common perception by the poor that environmental quality is an important determinant of their health, earning capacity, security, energy supplies, and housing quality (Brocklesby & Hinshelwood, 2001). Rural studies often observe that poor people's economic dependence on natural resources makes them particularly vulnerable to environmental degradation (Ambler, 1999; Cavendish, 1999, 2000; Kepe, 1999; Reddy & Chakravarty, 1999). Other studies have assessed the health damage suffered by poor households that are directly exposed to pollution of the air, water, and land (Akbar & Lvovsky, 2000; Bosch *et al.*, 2001; Brooks & Sethi, 1997; Mink, 1993; Songsore & McGranahan, 1993; Surjadi, 1993). In addition, environmental disasters and environment-related conflicts may have regressive impacts because the poor are least capable of coping with their effects (Albla-Betrand, 1993; Myers & Kent, 1995).

In some cases, poor households themselves may increase environmental degradation.

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Poverty-constrained options may induce the poor to deplete resources at rates that are incompatible with long-term sustainability (Holden, 1996). In such cases, degraded resources precipitate a "downward spiral," by further reducing the income of the poor (Cleaver & Schreiber, 1994; Dasgupta & Mäler, 1994; Durning, 1989; Ekbom & Bojö, 1999; Mink, 1993; Pearce & Warford, 1993; Prakash, 1997; World Bank, 1992; World Commission on Environment & Development, 1987). Rapid population growth, coupled with insufficient means or incentives to intensify production, may induce overexploitation of fragile lands on steep hillsides, or invasion of areas that governments are attempting to protect for environmental reasons. Again, a downward spiral can ensue (World Bank, 1992).

The existing literature also suggests that the strength of poverty–environment linkages may be affected by factors as diverse as economic policies, resource prices, local institutions, property rights, entitlements to natural resources, and gender relations (Ambler, 1999; Arnold & Bird, 1999; Barbier, 2000; Dasgupta & Mäler, 1994; Dutt & Rao, 1996; Ekbom & Bojö, 1999; Eskeland & Kong, 1998; Heath & Binswanger, 1996; Leach & Mearns, 1991; Roe, 1998). This research suggests that the relative strength of links between poverty and environment may be very context specific (Bucknall, Kraus, & Pillai, 2000; Chomitz, 1999; Ekbom & Bojö, 1999). In a recent theoretical work, Ezzati, Singer, and Kammen (2001) have demonstrated the implications for the Environmental Kuznets Curve (EKC). In a long-run model that allows for many interactions between socioeconomic and environmental variables, they show that the conventional, U-shaped EKC describes only one of many potential development paths. [2]

What does the empirical evidence suggest about the actual prevalence and importance of the poverty–environment nexus and complementary problems? Here the actual record is sparse, because the requisite data are often difficult to obtain in developing countries. In principle, household-level studies can adequately test whether environmental problems have a disproportionate impact on the poor. In practice, such tests are rare. For example, some studies have established a link between poverty and consumption of wood fuel, and at least, one credible study has established the relationship between indoor combustion and health (Ezzati & Kammen, 2001). However, the research also suggests the importance of intervening variables such as cooking practices (indoor *vs.* outdoor) and fuel choice (e.g., charcoal emits far fewer fine particles than wood). Children die of waterborne disease at higher rates in poor households, but again, research points to the significance of intervening variables such as water source quality and mother's education (Filmer & Pritchett, 1997; Merick, 1985). Rigorous empirical studies that combine local-area environmental variables (deforestation, outdoor air quality, water quality, soil erosion, etc.) with standard household surveys are almost nonexistent. Similarly, very few local-area studies relate environmental quality to the number and characteristics of poor households.

In poverty–environment analysis that is relevant for policy, the spatial dimension is critical for two reasons: First, most environmental problems are inherently geographical. In principle, different environmental problems should be analyzed at different regional scales. In the case of pollution, for example, the theoretically appropriate scale is affected by the dispersal characteristics of the pollutant and medium: Particulate pollution from cement mills may only be dangerous in one urban region; acid rain from sulfur emissions may damage forests hundreds of miles from the source; and eutrophication from fertilizer runoff may affect ocean fisheries a thousand miles downstream from the farms that are the source of the problem. In practice, data constraints often dictate the choice of the scale. In Cambodia, Vietnam, and Lao PDR, for example, appropriate data are relatively plentiful at the provincial level, scarce at the district level (except in Cambodia), and practically nonexistent for subdistricts. Accordingly, this paper focuses on provincial data, with extensions to the district level for Cambodia. While we readily acknowledge that more disaggregated evidence would be desirable, we believe that even province-level analysis provides a useful first approximation for poverty–environment work.

We also recognize the possibility that cross-country externalities may introduce elements of the nexus at the regional level, as we have noted in the previous paragraph. If much of pollution's impact is felt far downwind or downstream, failure to find a nexus in the local data may simply mask trans-boundary effects. For some pollutants (e.g., acid rain and deforestation from industrial sulfur emissions), this may indeed be a problem. However, a large body of evidence indicates that local impacts predominate for pollutants that most heavily affect the poor. The foremost examples are fine particulate air pollution, which causes the bulk of cardiorespiratory problems, and fecal coliform pollution of water, which is the major cause of intestinal disease. Most particulate air pollution settles locally; locally generated "plumes" of fecal coliform pollution generally persist for several miles downstream, but would present trans-boundary problems only in border areas.

At the provincial level, a minimum criterion for potential significance of the nexus is disproportionate environmental damage in high-poverty areas. Correlation does not necessarily imply causality, of course, but the lack of time series data prevents formal testing of structural causation models. [3] Nevertheless, some reasonable inferences from positive correlations are possible. We can also gain an insight from contrary cases, in which some of a country's environmental problems exhibit no spatial correlation with poverty across provinces. At least three inferences are possible: The country's poverty–environment nexus may not include these problems; the government may already have addressed them effectively; or their part of the nexus may only be operative at the district or subdistrict level. Data permitting, further tests could be run at those levels.

Administrative economics provide the second rationale for spatially disaggregated analysis. An appropriate geographic scale must strike an appropriate balance between the benefits of decentralization and the associated costs. On the environment side, for example, effective regulation requires local inspection of damage sources (pollution, deforestation, etc.), as well as more centralized facilities for information collection, storage, and analysis. Environmental management is undoubtedly improved by a knowledge of local conditions, but the marginal cost of administration rises with distance from administrative centers, because of deteriorating transport and communications quality. Generally, province- or district-level administration strikes the right balance between headquarters scale economies and the cost of dispersed monitoring and enforcement operations.

Similar factors govern the choice of administrative scale for poverty-alleviation programs. Headquarters staffing remains important, but such programs also require local monitoring information and frequent interaction with clients. By the same logic, province- or district-level administration may be preferable to national or subdistrict administration in many cases.

Why are these factors important for analysis of the poverty–environment nexus? From a policy perspective, the nexus is important only if it has consequences for the allocation and administration of public resources for alleviation of poverty and environment problems. If there is no nexus, then optimal policy should treat the two sectors as separate, divide the overall budget between them by some criteria, and use separate calculations to distribute resources among provincial or district agencies. If poverty–environment links are strong, on the other hand, then optimal policy should treat them jointly in allocating the overall budget. Some resources for environmental improvement should be allocated to poverty alleviation when poverty significantly increases environmental degradation, and the converse should hold when environmental factors significantly increase poverty.

In this paper, we use newly available data to test for the existence of the nexus in Cambodia, Lao PDR, and Vietnam. Our main analytical tools are georeferenced indicator mapping, correlation, and regression analysis. [4] We recognize that systematic empirical work is only beginning in this area; future work may reveal that the regional scale of our analysis is too broad, and that the "true" poverty–environment nexus is more localized in nature. It is also entirely possible that different dimensions of the nexus are best analyzed at different geographical scales. For example, watersheds may provide the best spatial units for the study of relationships linking poverty, soil erosion, and deforestation. [5] At present, the available data limit us to the broader exercise that is presented here. In addition, our focus on the comparative incidence of poverty–environment problems leads us to focus the exercise at a common geographical scale.

The remainder of the paper is organized as follows: Section 2 provides an overview of the methods that we employ and relates them to underlying hypotheses about links between poverty and the environment. Section 3 introduces the new regional dataset for Cambodia, Vietnam, and Lao PDR, with particular attention to the data-collection process, coverage, and accuracy. In Section 4, we provide a detailed illustration of our approach for Cambodia. Section 5 summarizes comparable evidence for Lao PDR and Vietnam, [6] Section 6 discusses some causal implications of the results, and Section 7 concludes the paper.

2. MAPPING THE PROBLEMS

(a) *Absolute poverty*

For each country, our provincial or district-level absolute poverty indices are determined by the number of inhabitants whose daily consumption expenditure cannot support a food intake of more than 2,000 calories, plus minimal nonfood expenditures. By this measure, the national incidence of absolute poverty is 36% in Lao PDR, 40% in Cambodia, and 37% in Vietnam. [7] To illustrate, Figure 1 displays the regional distribution of absolute poverty in Cambodia.

We vary our use of the absolute poverty measure according to the nature of each environmental problem. For example, we employ both the size of the poverty population and the poverty head-count ratio (or incidence) in our regression analyses of the relationships linking poverty to illness from indoor air pollution and polluted water. [8, 9] For our analysis of deforestation, we use the density of the poverty population per unit area. [10]

Even though absolute material poverty provides a useful indicator, we recognize that no single measure can capture all the dimensions associated with a broader concept of poverty. For an analysis of the poverty–environment nexus, other relevant factors may include lack of access to common property resources, poor health, and low levels of education. For example, research on China and Indonesia has suggested that education reduces pollution damage because better-educated communities are more willing and able to organize to control polluters. [11] As better data become available, more fully specified models should incorporate such factors. In this study, the consequences of our reliance on a single poverty index are ambiguous. Exclusion of poverty dimensions that are correlated with material poverty may result in overestimation of its impact in our correlation and regression analysis. On the other hand, exclusion of these other dimensions also suppresses their potentially significant two-way interactions with environmental variables.

(b) *Environmental problems*

We consider five critical environmental problems, two related to natural resource degradation and three to pollution. The "Green" problems are deforestation and soil degradation, whereas the "Brown" problems are indoor air pollution, contaminated water, and outdoor air pollution.

(i) *Deforestation*

Deforestation serves as a proxy for the loss of critical ecosystems and biodiversity, as well as increased risk of soil erosion in steeply sloped areas. To test for a poverty–environment nexus in this context, we map forested areas and rates of deforestation by province and district. In

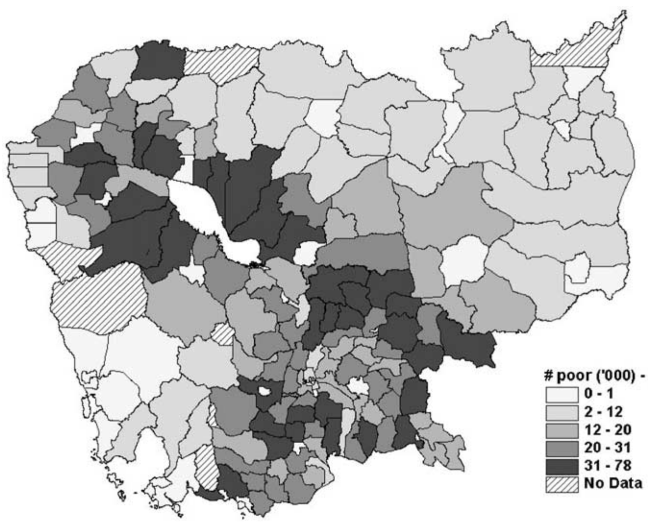

Figure 1. *Cambodia: total poverty population by district, 2000. Source: World Food Program, 2001.*

areas where significant forests remain, we assess the spatial correlation of poverty and deforestation using maps, graphical scatter plots, and regressions.

For the regression analysis, our two principal variables are the settlement density of the poor population and overall population density. [12] By incorporating both, we can simultaneously test the impact of poor and nonpoor households on forest clearing. [13] Insignificance of settlement density for the poverty population in this regression would certainly weaken the nexus argument that poor households clear forests more rapidly than others. We cannot test the converse proposition (exogenously generated deforestation increases poverty) until we have better information about the dependence of the poor on forest products. Future research should use local data for a more detailed analysis of this potential link.

We also test for the impact of commercial logging by controlling for differences in tree species. In our three study countries, some area experts have suggested that deforestation is significantly faster in areas dominated by evergreens, which are the preferred species for commercial loggers.

(ii) *Fragile soils*

Steep hillsides under intensive cultivation are particularly vulnerable to erosion and soil degradation without terracing, and the economic return to farming steeply sloped areas is generally lower than the return to cultivating alluvial soils in river valleys. While these observations are straightforward, their implications for the poverty–environment nexus depend on local possibilities for migration. In regions where people are relatively free to migrate to areas with higher expected returns, we would expect steeply sloped areas to be more sparsely populated than alluvial plains. If population growth raises the labor intensity of alluvial farming, we would expect diminishing returns in the lowlands to induce uphill movement by farmers. This movement would be tempered by erosion and soil depletion in the highlands, with a consequent drop in the overall marginal productivity of agricultural labor. The remaining highland farmers should farm larger plots, on average, to compensate for poorer soils and to maintain parity in expected income with lowland farmers. Damage to highland soils would be a resource conservation problem for society as a whole, but would not have a disproportionate impact on the poorest farmers if they remained free to migrate.

A very different picture would emerge, however, if marginalized ethnic groups were isolated in highland areas by historical patterns of separation and discrimination. In this case, population growth and soil degradation in the highlands might well create a "poverty trap" there. By implication, a potential poverty–environment nexus exists in regions where poor households are highly concentrated in steeply sloped areas.

(iii) *Indoor air pollution*

Recent research has suggested that indoor air pollution from wood fuels is a major cause of respiratory disease in developing countries. Many households use wood or charcoal in Cambodia, Lao PDR, and Vietnam, so indoor air pollution may be a significant health problem. Although indoor air monitoring data are not yet available in the region, household surveys have recorded the use of wood and charcoal. We use regression analysis to test whether poverty and wood fuel use are significantly associated, after controlling for area population. We recognize that our results can only be suggestive, since the impact of wood fuel use depends on whether burning is indoors or outdoors. Gauging the true magnitude of the problem will require household-level pollution monitoring and health assessment. This should be an important topic for future research in our focal countries.

(iv) *Access to clean water and sanitation*

Safe water and adequate sanitation are critical determinants of health status, particularly for children. Ingestion of coliform bacteria from contaminated drinking water or food is a prime cause of diarrheal disease, which is in turn a major cause of infant mortality in developing countries. Although data for Southeast Asia remain limited, we use the available information to assess the spatial relationships linking poverty, sanitation, and diarrheal disease. At present, many households in the three countries do not have access to safe water or sanitation. A poverty–environment nexus exists if the affected households are disproportionately poor. We use maps, scatter plots, and regressions to test for this possibility.

(v) *Outdoor air pollution*

Outdoor air pollution is primarily an urban phenomenon, whose severity depends on the scale of polluting activities, their pollution intensity (or pollution per unit of output), and the characteristics of the urban air shed. Recent research has established that exposure to fine particulates (with diameters of 10 microns (PM_{10}) or less) is the main cause of pollution-related respiratory disease. Until recently, little was known about fine-particulate pollution in Southeast Asian cities. During the past year, however, the World Health Organization and the World Bank have used a large international database to develop a prediction model for PM_{10} pollution, based on urban population, income, fuel use, and local atmospheric characteristics (wind, rainfall, temperature, altitude, etc.). [14]

We measure the health impact of PM_{10} pollution using a standard "dose–response" function, based on population exposure studies, that relates the incidence of mortality to the airborne concentration of PM_{10}. [15] For each urban area in Cambodia, Lao PDR, and Vietnam, we use the World Bank/WHO model to predict the airborne concentration of PM_{10}, transform the concentration to an estimated mortality incidence using the dose–response function, and multiply the predicted incidence by the urban population to obtain estimated deaths from air pollution. We cannot adjust specifically for the impact of air pollution on the poor, because the existing dose–response functions do not distinguish between income groups. It seems likely that our approach underestimates health damage to the poor, who are generally unable to afford health care that can (at least partially) compensate for the effect of air pollution.

We would, of course, prefer to base our estimates on actual monitoring data. However, to our knowledge, previous environmental studies have not even attempted to estimate air pollution for cities in the region. We therefore offer these estimates as a suggestive benchmark for further research. Aggregation of the urban-area results to the provincial level enables us to test for a poverty–environment nexus by assessing the spatial correlation between poverty and health damage from outdoor air pollution.

3. REGIONAL DATASETS FOR CAMBODIA, VIETNAM, AND LAO PDR

Work on the poverty–environment nexus requires spatially integrated information, but the underlying problems have traditionally received separate treatment. The spatial dimension of poverty has probably received the most attention. In our three focal countries, for example, poverty mapping has been supported by the World Food Program and the World Bank in Cambodia, the International Food Policy Research Institute (IFPRI) in Vietnam, and the World Bank in Lao PDR.

Support for spatially oriented work on the environment has been scattered among agencies that have interests in different topics. The Mekong River Commission has supported work on deforestation, terrain slopes, erosion, and water quality in our three focal countries. As previously mentioned, the World Health Organization and the World Bank have estimated air pollution for cities with over 100,000 in population as part of an international program.

Various household survey exercises have provided critical information for the analysis of health damage from water pollution and indoor air pollution. For Cambodia and Vietnam, USAID has sponsored regionally coded Demographic and Health Surveys (DHS) that include data on intestinal illness, respiratory disease related to air pollution, and the use of biomass fuels that are major determinants of indoor air pollution. Population census data for Cambodia provide regionally coded information on households' access to safe drinking water and sanitation.

When this study began, these critical information sources were scattered among international agencies, local development research institutes, and government ministries that had sponsored or participated in the work. Accessing the data involved several trips to the three countries by a team of World Bank staff members and consultants, including the authors. The World Bank's Spatial Analysis Team incorporated the information into the spatially integrated dataset that has been used for this paper.

Most topical components of the data (e.g., poverty incidence, intestinal illness from water pollution) reflect sophisticated survey and mapping work by experienced international teams. National population census surveys have also employed standard sampling methods. For this analysis, the major problem has not been the quality of the underlying data, but rather the appropriate level of spatial integration. Some geophysical data (e.g., forest coverage, terrain maps) have very high levels of spatial disaggregation, while the coverage of some household survey data (e.g., the DHS survey for Vietnam) is only sufficient to support reliable estimation at the provincial level. To maintain an integrated view, we have analyzed the data at the greatest common level of disaggregation available in each country. Accordingly, we have analyzed the Cambodian data at the district (subprovincial) level, while limiting the exercise to the provincial level in Lao PDR and Vietnam.

4. EVIDENCE FOR CAMBODIA

To provide the most disaggregated view of the evidence, we begin with the district-level analysis for Cambodia. Figure 1 provides the best available map of Cambodia's poverty population at the district level: Poor households are concentrated along an axis that runs northwest to the border with Thailand. Figure 2, which displays variations in the density of the poverty

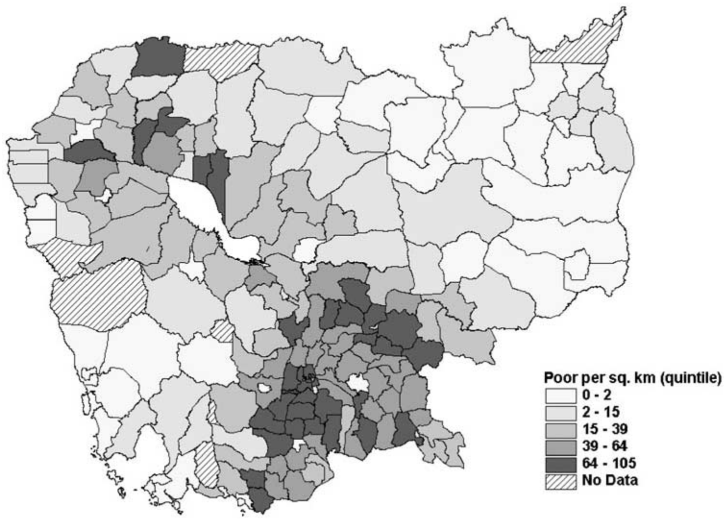

Figure 2. *Cambodia: settlement density of the poverty population. Source: World Food Program, 2001.*

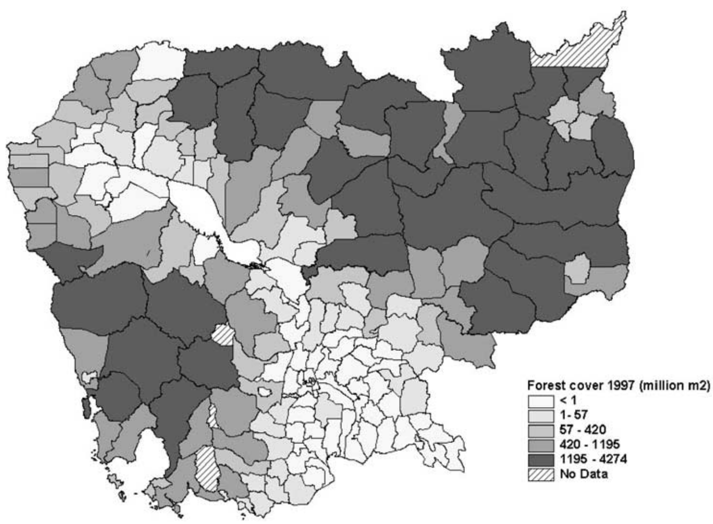

Figure 3. *Cambodia: forested area, 1997. Source: Mekong River Commission (MRC), 2001.*

population, suggests that provision of services to the poor would have the lowest unit cost in the southeastern part of the axis.

Figures 3 and 4 provide maps of Cambodia's forest cover and rate of deforestation for the period 1993–97. Figure 4 suggests that deforestation is a major problem at the margin of the central population axis; many contiguous districts have very high deforestation, and many areas, one district removed, also have high rates. The other region with rapid deforestation is the sparsely populated northeast. For the country as a whole, a comparison of Figures 1 and 4 suggests that priority areas for poverty alleviation and forest protection are weakly related because many of the core poverty areas are already deforested. The scatter diagram in Figure 5 confirms this, showing a nearly random relationship with a rank correlation of 0.15.

Our regression results (Table 1) suggest that overall population pressure is a major determinant of deforestation in Cambodia. However, the results also suggest that forest clearing by poor people is neither more nor less intensive than forest clearing by the general population. In the Cambodian regressions, introduction of explicit controls for species yields no higher deforestation rate for evergreens, which are reputed to be more lucrative for loggers.

Figure 6 uses the incidence of steeply sloped lands to map the potential for erosion and soil

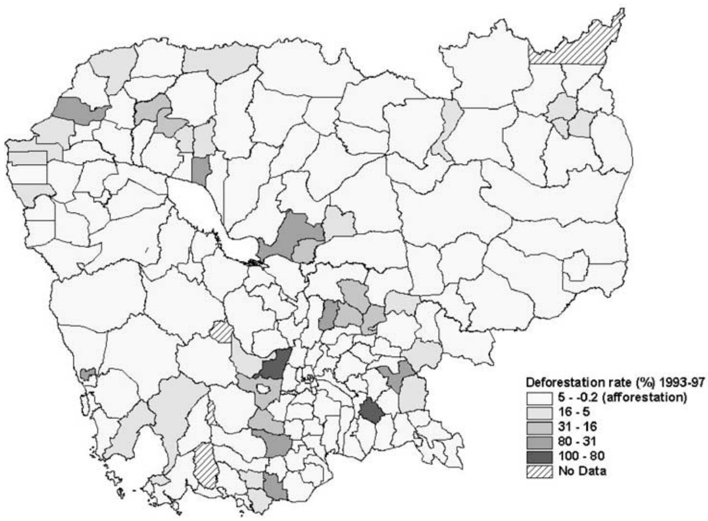

Figure 4. *Cambodia: deforestation rate, 1993–97. Source: Mekong River Commission (MRC), 2001.*

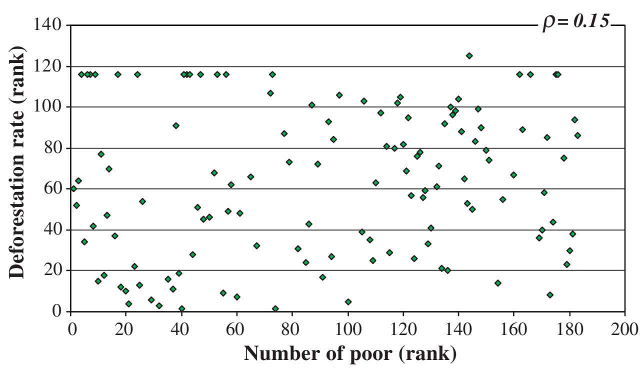

Figure 5. *Cambodia: rank scatter: deforestation rate versus poverty population.*

Table 1. *Cambodia: population, poverty and deforestation*

Variable	Model 1	Model 2	Model 3
Log(Poor/Forest cover 93)	−0.007	−0.007	
Log(Population/ Forest cover 93)	−0.010	−0.011	−0.018**
Evergreen	0.052*	0.018	0.020
Deciduous	0.036		
Mixed	0.062**		
Constant	−0.014	0.030	0.039
N	369	369	369
R^2	0.065	0.056	0.052

Dependent variable: Log(Forest cover 1997/Forest cover 1993). Evergreen, deciduous, and mixed forest dummy variables.
* Significant at the 10% level.
** Significant at the 5% level.

depletion in Cambodia. Distinct highland areas are visible in the northeast, southeast, and particularly the southwest regions of the county. The country's central population axis, on the other hand, is effectively defined by the lowlands. Regions with intermediate topography are intermediate in settlement as well.

Comparison of Figures 1 and 6 suggests a negative relationship between settlement by the poor and steeply sloped land: Poor people are heavily concentrated in lowland areas and reside at a much lower density in highland areas. The map shows little evidence of large poverty populations in steeply sloped areas, suggesting relatively few cases of inability to migrate because of ethnic segmentation and discrimination. The scatter in Figure 7 confirms the negative relationship between poverty and steeply sloped land (simple correlation coefficient: −0.29), and is consistent with a model of relatively free migration in Cambodia.

Figure 8 displays the scatter plot of district-level poverty population *versus* population using fuel wood or charcoal. Obviously, the relationship is very close (the correlation coefficient is 0.70, with much of the remaining variation explained by the plot's obvious separation into two separate sets of points). However, the existence of a true poverty–environment nexus in this context depends on more intensive use of charcoal and wood fuel by poor households.

The results in Table 2 do, in fact, indicate a strong association between poverty and wood fuel use after we control for general population effects.

Figure 9 suggests a close spatial correlation between poverty and lack of access to clean water. Regression analysis (Table 3) also suggests that poor households have much less access to safe water than higher-income households in Cambodia. The implications for child mortality are suggested by Figure 10, which displays the regional distribution of childhood deaths in Cambodia. Again, the spatial correlation with the poverty population is evident.

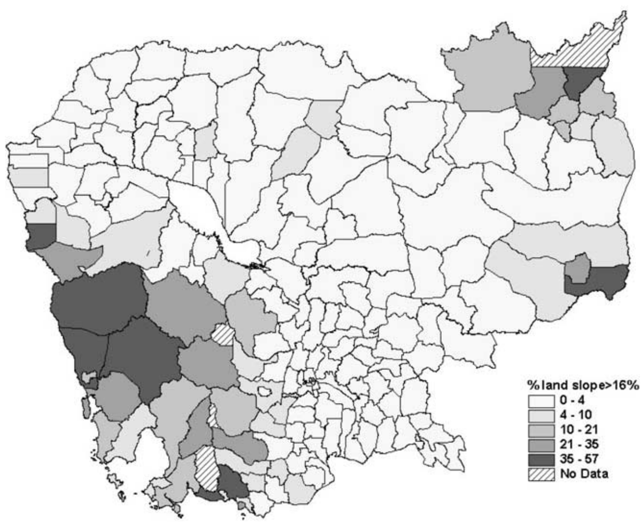

Figure 6. *Cambodia: percent of land that is steeply sloped. Source: Mekong River Commission (MRC), 2001.*

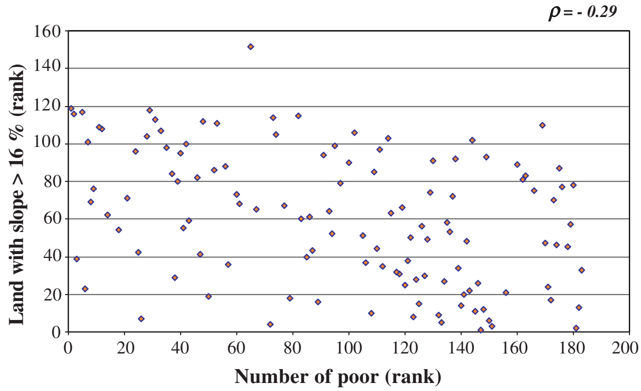

Figure 7. *Cambodia: rank scatter: steeply sloped land versus poverty population. Source: Mekong River Commission (MRC), 2001.*

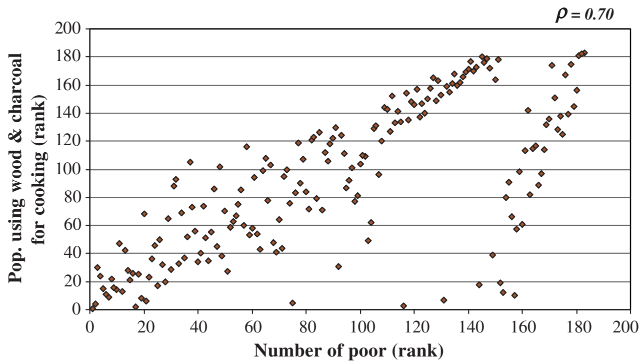

Figure 8. *Cambodia: rank scatter: fuel wood-using population versus poverty population. Source: Population Census, 1998.*

Table 2. *Cambodia: population, poverty and use of wood fuel and charcoal*

Variable	Model 1	Model 2
Total population	0.843**	
Number of poor	0.292**	
Log(Total population)		0.971**
Log(Number of poor)		0.013**
Constant	1101.698**	0.141**
N	180	180
R^2	0.979	0.994

Dependent variable: Model 1—Population using wood & charcoal; Model 2—Log(Population using wood & charcoal).
** Significant at the 5% level.

Using the WHO/World Bank model, we project PM_{10} pollution levels for urban areas in Cambodian cities. Figure 11 indicates that estimated pollution levels are generally higher in cities located in Cambodia's population periphery. Using a standard dose–response model, we estimate the resulting loss of life and aggregate the results to the provincial level. Our findings, displayed in Figure 12, suggest minimal correlation (0.14) between poverty population and deaths from air pollution.

Figure 13 summarizes the available evidence for Cambodia's poverty population, deforestation, steeply sloped land, indoor air pollution, unsafe water, child mortality, and mortality from outdoor air pollution. The elements of the matrix are numerically ranked by severity for ease of comparison. Figure 14 further condenses the evidence into average rankings for the first two ("Green") indices and the last three ("Brown") indices. The results seem consistent with a poverty–environment nexus for

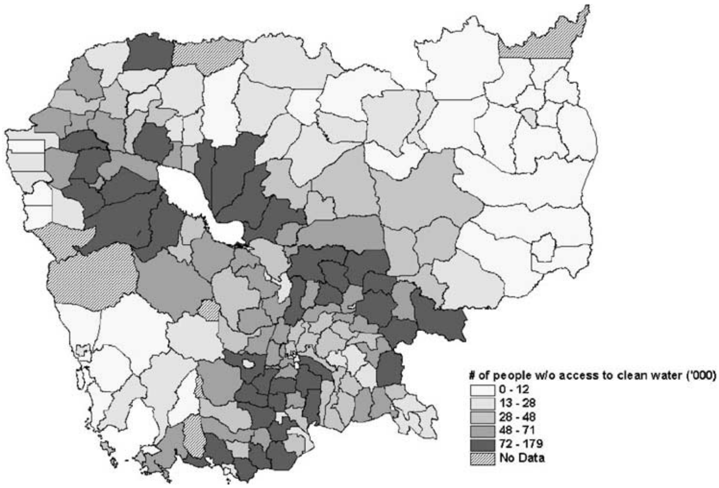

Figure 9. *Cambodia: population without access to clean water, 1998. Source: Population Census, 1998.*

Table 3. *Cambodia: population, poverty and access to safe water*

Variable	Model 1	Model 2
Total population	0.241**	
Number of poor	1.437**	
Log(Total population)		0.587**
Log(Number of poor)		0.186**
Constant	3071.133**	2.398**
N	180	180
R^2	0.847	0.664

Dependent variable: Model 1—Population without safe water; Model 2—Log(Population without safe water).
** Significant at the 5% level.

indoor air pollution and water contamination. However, there is no evident relationship between the spatial distributions of poverty and deaths from outdoor air pollution. Nor does there appear to be a significant spatial relationship between poverty and either of the Green indices. On the basis of currently available evidence, we conclude that the regional poverty–environment nexus in Cambodia is largely confined to household-level problems associated with contaminated air and water.

5. EVIDENCE FOR LAO PDR AND VIETNAM

Similar evidence for Lao PDR in Figure 15 suggests a poverty–environment nexus that is significantly broader than Cambodia's. Across provinces, Figure 15 shows a strong correspondence between poverty and environmental degradation in all five categories—deforestation, erosion potential, indoor air pollution, contaminated water, and outdoor air pollution. The association is particularly strong for the lowest- and highest-income provinces. When the environmental rankings are combined into "Green" and "Brown" indices, the association is clearer across all provinces. We conclude that the regional poverty–environment nexus seems very broad for Lao PDR, so the potential synergy between poverty alleviation and environmental policies may be very high. The north- and northeastern regions of the country appear to be the main locus for action in this context.

For Vietnam, the evidence in Figures 16–19 suggests a more limited poverty–environment nexus. The spatial correlation with the poverty population appears negligible for deforestation, very weak for sanitation and diarrhea, and negative for outdoor air population. However, the large poverty populations in steeply sloped areas suggest that ethnic separation has opened potential "poverty traps." Our evidence also suggests a relationship between poverty and indoor air pollution (indexed by cases of acute respiratory infection).

6. CAUSAL IMPLICATIONS OF HOUSEHOLD-LEVEL RESULTS

Although the lack of time series data prevents structural modeling, we believe that

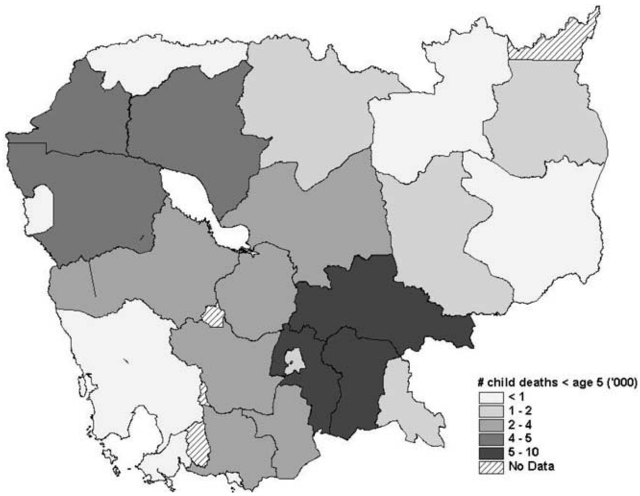

Figure 10. *Cambodia: child deaths, 1998. Source: Population Census, 1998.*

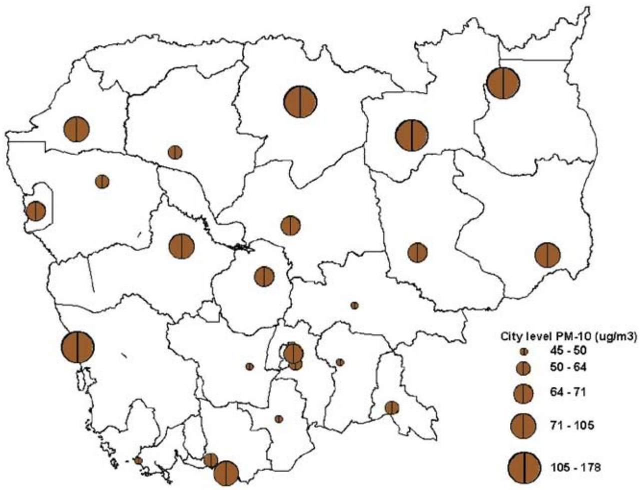

Figure 11. *Cambodia: urban PM-10 air pollution. Source: World Bank Estimates, 2004.*

reasonable inferences about causation are possible for our household-level results. First, we consider the evidence related to poverty and households' use of polluting wood fuels. In both Cambodia and Lao PDR, we find a strong, positive relationship between poverty and use of these fuels. At the same time, we find a generally weak relationship between poverty and deforestation. Since use of wood fuels promotes deforestation, these asymmetric results suggest that poverty contributes strongly to household air pollution, but that fuel wood use (through deforestation) may not contribute strongly to poverty.

Poverty, lack of access to clean water, and intestinal disease are also highly correlated in Cambodia and Lao PDR. In this case, it seems reasonable to infer two-way causation. *Ceteris paribus*, poverty limits access to clean water and sanitation. At the same time, sanitation-related diseases exacerbate poverty by reducing productivity and imposing significant health-care costs on affected households. However, the weaker relationship between poverty and

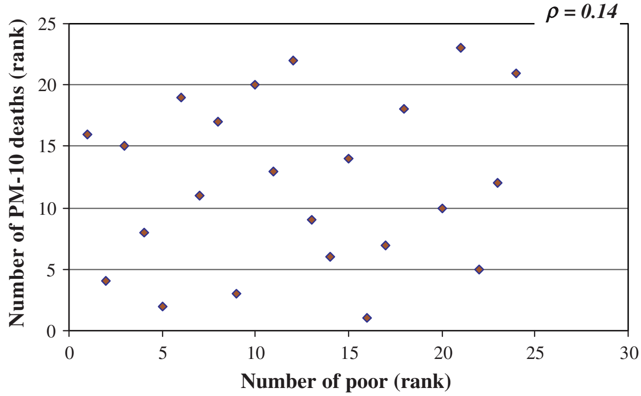

Figure 12. *Cambodia: rank scatter: PM-10 air pollution deaths versus poverty population.*

Province	Poor	Deforest	Slope	Wood/ Charcoal	Unsafe Water	Child Deaths	PM-10 Deaths
Kampong Chaam	1	1	3	1	1	1	3
Siem Reab	1	2	2	2	1	1	1
Prey Veaeng	1	1	4	1	2	1	3
Kampong Thum	1	3	4	2	1	2	2
Baat Dambang	1	3	2	1	1	1	1
Taakaev	1	1	3	1	1	2	4
Kandaal	2	4	4	1	1	1	2
Kampong Spueu	2	2	1	2	2	2	3
Banteay Mean Chey	2	1	3	2	2	1	1
Kampot	2	2	1	2	2	2	4
Kampong Chhnang	2	3	2	3	2	2	3
Svaay Rieng	2	1	4	2	3	3	4
Pousaat	3	4	1	3	2	2	2
Kracheh	3	4	3	3	3	3	1
Preah Vihear	3	3	2	3	3	3	3
Phnom Penh	3	4	4	1	3	3	1
Kaoh Kong	3	2	1	3	4	4	2
Rotanak Kiri	3	2	1	4	3	3	3
Otdar Mean Chey	4	1	3	4	4	4	–
Stueng Traeng	4	3	2	4	4	3	2
Mondol Kiri	4	4	1	4	4	4	4
Krong Preah Sihanouk	4	2	3	3	3	4	1
Krong Kaeb	4	4	4	4	4	4	2
Pailin	4	3	2	4	4	4	4

Note: "–" denotes no data for that province.
1—1st quartile; 2—2nd quartile; 3—3rd quartile; 4—4th quartile

Figure 13. *Cambodia: poverty population and environmental problems.*

sanitation in Vietnam suggests that public intervention can break this perverse link. The critical difference may lie in the Vietnamese government's relatively high level of investment in public health and education (particularly for women). Extensive literature has documented the significance of these factors in reducing disease and mortality, even where access to clean

Province	Poor	Green	Brown
Kampong Chaam	1	3	1
Siem Reab	1	2	1
Prey Veaeng	1	2	1
Kampong Thum	1	4	2
Baat Dambang	1	2	1
Taakaev	1	1	2
Kandaal	2	4	1
Kampong Spueu	2	1	2
Banteay Mean Chey	2	2	2
Kampot	2	1	3
Kampong Chhnang	2	3	3
Svaay Rieng	2	3	2
Pousaat	3	3	2
Kracheh	3	4	3
Preah Vihear	3	3	3
Phnom Penh	3	4	2
Kaoh Kong	3	1	3
Rotanak Kiri	3	1	4
Otdar Mean Chey	4	2	4
Stueng Traeng	4	2	4
Mondol Kiri	4	3	4
Krong Preah Sihanouk	4	2	3
Krong Kaeb	4	4	4
Pailin	4	3	4

Note: Green indicator index (equal weighting): (a) Deforestation rate, (b) slope greaterthan 16%;
Brown indicator index (equal weighting): (a) Number using wood and charcoal, (b) number of cases of diarrhea, (c) number without access to water and toilets, and (d) number of PM10 air pollution deaths.

Figure 14. *Cambodia: poverty population versus Green/Brown environmental problems.*

water is limited (Merick, 1985; Filmer & Pritchett, 1997).

7. SUMMARY AND CONCLUSIONS

In this paper, we have investigated the regional poverty–environment nexus in Cambodia, Lao PDR, and Vietnam. Our analysis has focused on spatial relations between poverty populations and environmental problems at the provincial and district levels (see the summary in Table 4).

We identify a potential poverty–environment nexus in cases where the pattern of regional settlement by poor households is strongly associated with each of five environmental problems: deforestation, fragile soils, indoor air pollution, contaminated water, and outdoor air pollution. Our results suggest that the nexus is quite different in each country. In Cambodia, it seems largely confined to household-level problems associated with indoor air pollution, contaminated water, and lack of access to adequate sanitation. Outdoor air pollution, deforestation, and fragile lands are not significantly associated with poverty at the district level. We conclude that poor households in Cambodia might benefit most strongly from programs that jointly address poverty and household-level environmental quality. At the same time, all of Cambodia's citizens, including the poor, would benefit from more effective measures to reduce the rate of deforestation.

Our results suggest a broader poverty–environment nexus in Lao PDR, since all five environmental problems exhibit a spatial correlation with poverty. The overlap is particularly strong in the northern and northeastern regions of the country. We conclude that the welfare of the poor in Lao PDR might be significantly enhanced by close integration of poverty-allevi-

Province	Poor	Deforest	Sloped	Wood/ Charcoal	Unsafe Water	Child Diarrhea	PM-10 Deaths
Savannakhet	1	4	4	1	1	1	1
Champasack	1	3	4	1	1	1	2
Huaphanh	1	2	1	2	1	1	1
Luangphrabang	1	1	1	1	1	1	1
Oudomxay	1	1	2	3	2	2	–
Saravane	2	3	3	2	2	2	2
Khammuane	2	4	3	2	2	1	2
Phongsaly	2	1	1	3	3	4	2
Xiengkhuang	2	2	1	3	2	3	3
Vientiane Municipality	3	1	4	1	4	4	1
Vientiane	3	2	2	2	3	3	4
Luangnamtha	3	1	2	4	3	3	3
Xayabouri	3	2	1	1	1	2	3
Bokeo	4	3	3	4	3	3	–
Attapeu	4	4	3	4	4	2	4
Borikhamxay	4	4	2	3	4	4	3
Sekong	4	3	4	4	4	4	4
Xaysomboon	4	4	4	4	4	4	–

Note: a "–" denotes no data for that province.

Figure 15. *Lao PDR: poverty population and environmental problems.*

ation and environmental strategies in all Green and Brown dimensions. A geographic focus on the north would appear to be most beneficial.

The case of Vietnam is more eclectic than the other two, suggesting the possibility of a poverty–environment nexus for fragile soils and indoor air pollution. We conclude that an appropriate poverty–environment strategy for Vietnam might focus on the living conditions of poor households in steeply sloped areas.

In summary, we find little evidence of a general poverty–environment nexus in our three study countries. Indoor air pollution is the only common issue, and its severity depends on heating and cooking practices that are little studied as yet. Our evidence suggests that the nexus concept can provide a useful catalyst for country-specific work, but not a general formula for program design. Joint implementation of poverty and environment strategies may be cost effective for some environmental problems, but independent implementation may be preferable in many cases as well.

We recognize that our analysis is far from exhaustive, and that other environmental problems may warrant close attention. Possible candidates include depleted and polluted fisheries, and excessive use of pesticides. Future research should explore these issues more fully. We also recognize that sub-district-level analysis might reveal stronger poverty–environment links, as well as providing a better guide for spatial targeting of regional programs. For this reason, we hope that future research projects will promote more extensive data collection and analysis at the local level.

In addition, we believe that regional coordination of poverty–environment programs may be useful, even in some cases where the poverty–environment nexus does not appear to be strong in all countries. A good example is provided by the links between poverty, access to safe water, and intestinal disease. As we have noted, the empirical nexus may be weaker in Vietnam because government intervention has already been effective. A regional program linking Vietnamese experts to counterparts in Cambodia and Lao PDR could be very appropriate in these circumstances.

Despite these caveats, we believe that our findings provide some insights for policy makers who are concerned about the poverty–environment nexus. Our results suggest that the nexus is country specific, and institutional factors may play an important role. Data on more countries would be required for an in-depth

Province	Poor	Deforest	Sloped	No Toilets	Child Diarrhea	Acute Respiratory Infections	PM-10 Deaths
Thanh Hoa	1	3	1	1	2	1	1
Nghe An	1	2	1	1	1	1	1
Ha Tay	1	4	4	2	1	1	2
An Giang	1	1	4	1	1	1	1
Dak Lak	1	2	2	1	1	1	2
Bac Giang	1	3	4	3	1	4	3
Nam Dinh	1		–	3	2	1	1
Son La	1	4	1	2	4	2	4
Can Tho	1	1	–	4	3	3	1
Dong Thap	1	1	–	4	2	1	2
Thai Binh	1		–	4	4	1	3
Kien Giang	1	2	4	1	2	2	2
Binh Dinh	1	3	2	1	2	3	1
Ha Tinh	1	4	3	2			3
Quang Ngai	1	2	2	1			3
Quang Nam	2	1	1	1	2	3	2
Phu Tho	2	3	3	3	3	2	2
Gia Lai	2	2	3	1			3
Hai Duong	2	2	4	4	3		1
Soc Trang	2	1	–	2	1	2	2
Thua Thien - Hue	2	2	2	1	3	4	2
Vinh Phuc	2	3	4	4	3	2	3
Hai Phong city	2	3	–	4	2	1	1
Lai Chau	2	2	1	2	1	2	4
Binh Thuan	2	2	3	1	4	4	1
Hoa Binh	2	2	2	3			4
Tien Giang	2	4	–	4	2	3	2
Ha Giang	2	3	1	2			4
Thai Nguyen	2	3	3	3	3	4	2
Lang Son	2	2	4	2	3	2	4

Note: a blank denotes no data for that province; a "–" for Slope means no land greater than 16%.

Figure 16. *Vietnam: poverty population and environmental problems (top 2 quartile provinces).*

analysis of the relationship between a country's institutions and the dimensions of its poverty–environment nexus. However, the available evidence for our three countries does provide some useful insights. In Vietnam, the poverty–environment nexus (indoor air pollution, fragile lands) is concentrated in northern and western highland areas dominated by ethnic minority populations. State policy has focused on outdoor air pollution much more than indoor air pollution; priority has been given to reducing infant mortality through provision of clean water; and administrators seem to have managed forest clearing to about the same degree in poverty and nonpoverty areas.

Several poorer regions of Lao PDR are inhabited by peoples who are ethnic minorities in Vietnam, and the administrative and development resources of the Lao government appear much more limited than those in Vietnam. The result of more limited intervention is apparently a broadening of the nexus, which replicates the crossborder highland problems of Vietnam but also includes water pollu-

Province	Poor	Deforest	Sloped	No Toilets	Child Diarrhea	Acute Respiratory Infections	PM-10 Deaths
Ben Tre	3	1	–	4			4
Ha Noi city	3		–	3	1	1	1
Hung Yen	3		–	4	4	3	4
Tra Vinh	3	1	–	1	3		4
Long An	3	4	–	2			2
Lao Cai	3	3	1	2	3	4	4
Tuyen Quang	3	4	2	3	3	3	4
Quang Binh	3	4	3	3			4
Ca Mau	3		–	3	4	3	2
Yen Bai	3	3	1	2			3
Quang Ninh	3	4	3	4			1
Bac Ninh	3		–	4	1	2	4
Lam Dong	3	3	2	2	1	3	2
Ninh Binh	3	4	–	4			3
Vinh Long	3	1	–	4	2	3	3
Cao Bang	4	4	2	2			4
Phu Yen	4	1	3	1			3
Khanh Hoa	4	1	1	1			1
Quang Tri	4	3	3	3	2	4	3
Ha Nam	4	4	–	4	4	2	4
Bac Lieu	4		–	2	4	4	3
Ninh Thuan	4	3	2	1			3
Ho Chi Minh city	4	4	–	3		2	1
Dong Nai	4	3	4	2			1
Bac Kan	4	4	2	4			4
Kon Tum	4	2	1	3			4
Binh Phuoc	4	4	–	3	4	3	4
Tay Ninh	4	1	4	4			3
Da Nang city	4	2	3	3		4	1
Ba Ria - Vung Ta	4	1	4	2			1
Binh Duong	4	1	–	3	4	4	2

Note: a blank denotes no data for that province; a "–" for Slope means no land greater than 16%.

Figure 17. *Vietnam: poverty population and environmental problems (bottom 2 quartile provinces).*

tion, deforestation, and outdoor air pollution. Cambodia's public resources and administration also appear weakly developed, but poverty among highland ethnic minority groups is less significant in this society. With no concentration of poverty in ethnic minority regions, externality-related environmental problems such as erosion, deforestation, and outdoor air pollution appear to be more evenly distributed across poor and nonpoor areas. However, development administration is weaker than in Vietnam, and the government has not yet been successful in addressing any of the household-level environmental problems that are highly correlated with poverty (indoor air pollution, contaminated drinking water, lack of access to sanitation). In Vietnam, by contrast, a relatively successful focus on water and sanitation problems seems to have reduced the provincial poverty–environment nexus to indoor air pollution in highland areas where biomass fuels predominate.

Even though our results suggest that the poverty–environment nexus can differ substantially

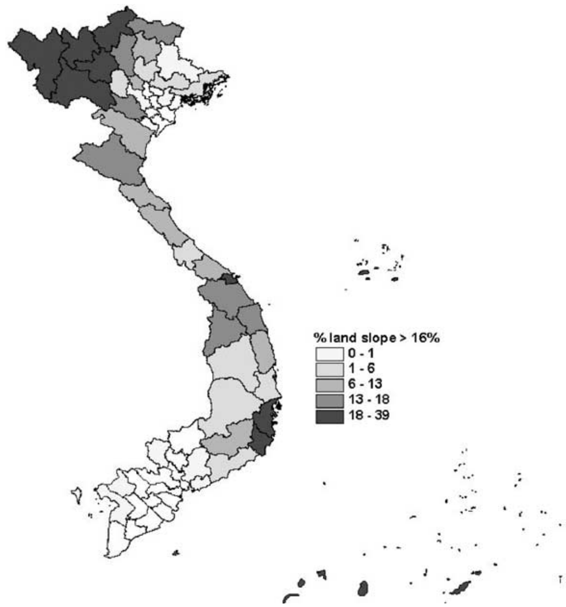

Figure 18. *Vietnam: steeply sloped land.*

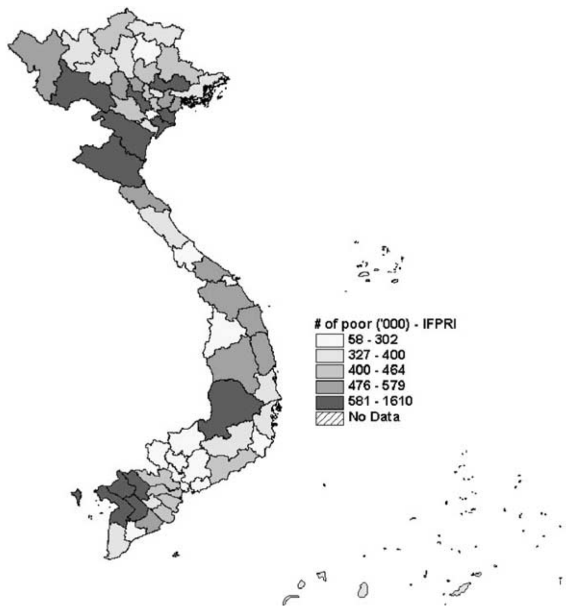

Figure 19. *Vietnam: poverty population, 1998. Source: IFPRI, 2001.*

across countries, we are only beginning to study the sources of these differences. We have suggested some reasons why the nexus seems to vary in Cambodia, Lao PDR and Vietnam, but the need for more comparative work is apparent. Since we have no clear basis for identifying country-specific limitations at this point, it seems advisable to begin future country analyses with a broad consideration of potential poverty–environment links. Starting with a

Table 4. *Summary of country-wide correlation with poverty*

PEN indicator	Cambodia	Lao PDR	Vietnam
1. Poverty/deforestation rate	Weak +ve correlation at the district level (prov.: $\rho = 0.46$) (district: $\rho = 0.15$)**	Weak +ve correlation at the provincial level (prov.: $\rho = 0.37$)**	Weak +ve correlation (Forestry data strongly questioned) (prov.: $\rho = 0.07$)*
2. Poverty/fragile land (slope > 16%)	Weak −ve correlation (prov.: $\rho = -0.29$) (district: $\rho = -0.29$)**	Weak +ve correlation (prov.: $\rho = 0.30$)**	Weak −ve correlation (prov.: $\rho = -0.10$)**
3. Poverty/indoor air pollution (wood/charcoal use)	Strong +ve correlation, supported by regression model (prov.: $\rho = 0.88$) (district: $\rho = 0.70$)***	Strong +ve correlation, supported by linear and log regression models (prov.: $\rho = 0.74$)***	No data on charcoal/wood use, however moderately correlated with ARI (prov.: $\rho = 0.51$)**
4. Poverty/access to clean water (CW), no sanitation (NS) & Diarrhea	Strong +ve correlation, supported by regression model	Strong (Water) and medium (Sani.) +ve correlations, as well as with Diarrhea cases	
	Water (prov.: $\rho_{cw} = 0.93$) (district: $\rho_{cw} = 0.85$)***	Water (prov.: $\rho_{cw} = 0.85$)***	Weak +ve correlation with toilet access, stronger with reported cases of diarrhea
	Sanitation (prov.: $\rho_{ns} = 0.95$) (district: $\rho_{ns} = 0.84$)***	Sanitation (prov.: $\rho_{ns} = 0.43$)**	Toilets (prov.: $\rho = 0.23$)**
	Diarrhea (prov.: $\rho = -0.28$)**	Diarrhea (prov.: $\rho = 0.75$)***	Diarrhea (prov.: $\rho = 0.44$)**
5. Poverty/outdoor air pollution (number of deaths from PM_{10})	Weak +ve correlation (prov.: $\rho = 0.14$)*	Strong +ve correlation (prov.: $\rho = 0.75$)**	Weak +ve correlation (prov.: $\rho = 0.27$)**
Overall poverty–environment nexus (PEN)	PEN largely confined to household-level problems due to contaminated air & water**	Spans most environmental indices considered***	Weaker compared to Cambodia and particularly Lao PDR. Data availability an important issue**

* Low correlation.
** Medium correlation.
*** High correlation.

broad "filter" also offers the prospect of more cost-effective approaches because it facilitates comparison across problems that are frequently addressed separately. In our three countries, for example, simultaneous attention to fragile lands and indoor air pollution facilitates comparison of intervention costs and potential benefits in the two dimensions. [16]

NOTES

1. Extensive research has explored the relationship between environmental degradation and economic growth. See particularly the special issues of the *Journal of Environment and Development Economics, 2*(4), 1997 and *Ecological Economics, 25*(2), 1998.

2. See Dasgupta, Laplante, Wang, and Wheeler (2002) for a related discussion of policy impacts on the EKC in developing countries.

3. We recognize that structural models will be difficult to estimate reliability for quite some time, since a relatively long time series would be necessary to distinguish two-way impacts of poverty and environmental variables from long trends produced by forces such as demographic change.

4. Henninger and Hammond (2000) make a strong case for using poverty–environment maps, which afford unique insights into the importance of spatial relationships.

5. We are indebted to an anonymous reviewer for this point.

6. We abbreviate the presentation for Lao PDR and Vietnam to keep the paper's length tractable, and because our analytical methods are identical to those used for Cambodia. For a full presentation and discussion of the evidence for Lao PDR and Vietnam, see Dasgupta, Deichmann, Meisner, and Wheeler (2004).

7. The minimum consumption and poverty estimates have been produced by the World Bank for Lao PDR, the World Food Program for Cambodia, and the International Food Policy Research Institute for Vietnam.

8. See the district-level Model 2 results for Cambodia in Tables 2 and 3. Our model relates an environmental problem (H) to the poverty count (P), population (N) and head-count ratio (P/N) as follows:

$$\log H_i = \alpha_0 + \alpha_1 \log\left(\frac{P_i}{N_i}\right) + \alpha_2 \log P_i + \alpha_3 \log N_i$$
$$= \alpha_0 + (\alpha_1 + \alpha_2)\log P_i + (\alpha_3 - \alpha_1)\log N_i.$$

We use the latter expression for estimation.

9. For Lao PDR, the available data have also enabled us to test the effect of the poverty gap (the difference between actual income and the absolute poverty line for a representative individual). For each province, we have estimated the total poverty gap by summing across gaps for all individuals who are estimated to fall below the poverty line. However, we find the correlation of this variable with the poverty count (.96) to be so high that the poverty count seems sufficient for our analysis.

10. See section (b) for a further discussion of the deforestation model.

11. For a further discussion, see Dasgupta and Wheeler (1997) and Pargal and Wheeler (1996).

12. Our regression analysis is based on a model of deforestation in which the representative individual in a region's population clears α hectares of forest annually. Forest loss in the region between period 0 and period t is therefore represented by $F_t - F_0 = \alpha N$ ($\alpha < 0$ for deforestation), where F is the forested area and N is the regional population. Dividing through by forested area in period 0 and changing to a logarithmic approximation, we obtain

$$\frac{F_t - F_0}{F_0} = \frac{\alpha N}{F_0} \quad \Rightarrow \quad \log\left(\frac{F_t}{F_0}\right) = \beta_0 + \beta_1 \log\left(\frac{N}{F_0}\right).$$

To allow for differential poverty effects, we generalize this expression to

$$\log\left(\frac{F_t}{F_0}\right) = \beta_0 + \beta_1 \log\left(\frac{N}{F_0}\right) + \beta_2 \log\left(\frac{P}{F_0}\right) + \beta_3 \log X,$$

where P is the region's poverty population and X represents other factors. In this model, β_1 reflects the average area cleared by each resident (poor or nonpoor), and β_2 measures the difference (if any) attributable to poverty.

13. We recognize that the estimated impact of settlement density may be biased by the exclusion of information on transport costs and other factors that affect settlement location, income, and deforestation. However, our test remains useful if the degree of bias is similar for poor households and households in general. For a further discussion, see Cropper, Griffiths, and Mani (1999).

14. See Pandey *et al.* (forthcoming).

15. For a further discussion of the relationship between outdoor air pollution and health, see Holgate, Samet, Koren, and Maynard (1999) and WHO (2000).

16. Our thanks to an anonymous reviewer for stressing this implication of the work.

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