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# The causes of land-use and land-cover change: moving beyond the myths

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**Abstract**

Common understanding of the causes of land-use and land-cover change is dominated by simplifications which, in turn, underlie many environment-development policies. This article tracks some of the major myths on driving forces of land-cover change and proposes alternative pathways of change that are better supported by case study evidence. Cases reviewed support the conclusion that neither population nor poverty alone constitute the sole and major underlying causes of land-cover change worldwide. Rather, peoples' responses to economic opportunities, as mediated by institutional factors, drive land-cover changes. Opportunities and

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constraints for new land uses are created by local as well as national markets and policies. Global forces become the main determinants of land-use change, as they amplify or attenuate local factors. 

## 1. Introduction

The pace, magnitude and spatial reach of human alterations of the Earth's land surface are unprecedented. Changes in land cover (biophysical attributes of the earth's surface) and land use (human purpose or intent applied to these attributes) are among the most important (Fig. 1) (Turner et al., 1990; Lambin et al., 1999). Land-use and land-cover changes are so pervasive that, when aggregated globally, they significantly affect key aspects of Earth System functioning. They directly impact biotic diversity worldwide (Sala et al., 2000); contribute to local and regional climate change (Chase et al., 1999) as well as to global climate warming (Houghton et al., 1999); are the primary source of soil degradation (Tolba et al., 1992); and, by altering ecosystem services, affect the ability of biological systems to support human needs (Vitousek et al., 1997). Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson et al., 1995).

Despite improvements in land-cover characterization made possible by earth observing satellites (Loveland et al., 1999), global and regional land covers and, in particular, land uses are poorly enumerated (IPCC, 2000). Scientists recognize, however, that the magnitude of change is large. One estimate, for example, holds that the global expansion of croplands since 1850 has converted some 6 million km$^2$ of forests/woodlands and 4.7 million km$^2$ of savannas/grasslands/steppes. Within these categories, respectively, 1.5 and 0.6 million km$^2$ of cropland has been abandoned (Ramankutty and Foley, 1999). Land-cover modifications—changes in the structure of an extant cover of a short duration (such as forest succession under slash-and burn cultivation)—are also widespread.

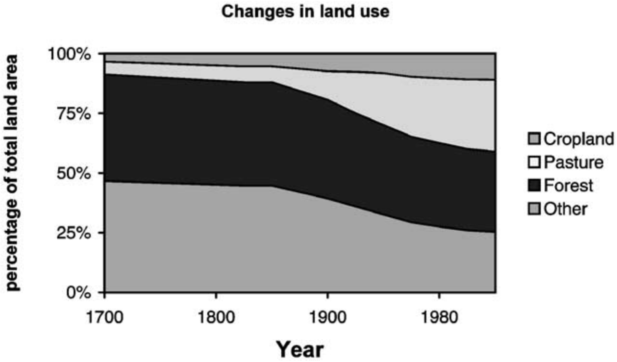


Fig. 1. Estimated changes in land use from 1700 to 1995 (Goldewijk and Battjes, 1997).

Better data alone are insufficient for improved models and projections of land-use and land-cover change. They must be matched by enhanced understanding of the causes of change (Committee on Global Change Research, 1999), and this requires moving beyond popular "myths". Such myths are simplifications of cause–consequence relationships that are difficult to support empirically but have gained sufficient public currency to influence environment and development policies. Popular status is gained because the simplification fits within prevalent worldviews, suggests simple technical or population control solutions, and may serve the interests of critical groups. Such simplifications rest on generalised models of change which may be insecurely linked to the large body of case study reports in the literature. Global scale assessments may therefore conflict with the findings of micro- or meso-scale data sets which, because they are specific to time and place, do not impact on the global debate. Therefore, 26 researchers, representing a variety of disciplines, and having extensive knowledge of case studies around the world, recently met to assess the state of understanding on land change. It is not possible to summarise the output of such an analysis in quantifiable form, as every case is unique. Instead, consensual judgements were constructed on the main simplifications. These are argued below, with the objective of strengthening the linkage between case study experience and global assessments.

The following classes of land change were examined: tropical deforestation, rangeland modifications, agricultural intensification and urbanization. Such efforts, supported by quantitative assessments, will lead to a deeper and more robust understanding of land-use and land-cover change and to more appropriate policy intervention. Improved understanding is also required to assess and project the future role of land-use and land-cover change in the functioning of the Earth System.

## 2. Tropical deforestation

### 2.1. *Simplification: Population and poverty drive deforestation, mostly through shifting cultivators' land use*

High rates of deforestation within a country are most commonly linked to population growth and poverty, shifting cultivation in large tracts of forests (Mather and Needle, 2000). The misconception that follows is that most tropical deforestation occurs by the "push" of population growth and poverty to invade, slash, and burn the forest along the roads (e.g. Allen and Barnes, 1985).

While not denying a role of population growth or poverty, most case studies fail to confirm this simplification in lieu of other, more important, if complex, forces of tropical deforestation (Anderson, 1996; Rudel and Roper, 1996; Fairhead and Leach, 1996; Barraclough and Ghimire, 1996). Results of careful surveys of tropical deforestation support the view that population growth is never the sole and often not even the major underlying cause of forest-cover change (Angelsen and Kaimowitz, 1999; Geist and Lambin, 2001). Where deforestation is linked to the increased presence of shifting cultivators, triggering mechanisms invariably involve changes in frontier development and policies by national governments that pull and push migrants into sparsely occupied areas (Rudel, 1993). In some cases, these "shifted" agriculturalists exacerbate deforestation because of unfamiliarity with their new environment; in other cases, they may bring new skills and understandings that have the opposite impact. The critical point, however, is that tropical deforestation is driven largely by changing economic opportunities which, as shown below, are linked to yet other social, political, and infrastructural changes (Hecht, 1985).

### 2.2. *The not-so-simple pathways of tropical deforestation*

Large-scale deforestation in the humid tropics is predicated on the existence of large, sparsely occupied forest regions in which the indigenous inhabitants have little or no power to influence the exogenous forces acting upon them and the land. In-migration is triggered by government decisions to open the frontier through settlement schemes, development projects, and plantations or through extractive industries, basically timber, with the spin-off consequences of "spontaneous" colonization. In either case, infrastructure development follows in the form of roads, electrification, health services and/or potable water, which attracts land-seeking families, and consolidates occupation. The deeper reasons for the government decisions include the desire to secure territorial claims and national political support, to attract international capital, to facilitate market opportunities, or to promote the interests of specific groups through exploiting natural resources controlled by the state. These motivations, the relative role of settlement-project development and timber extraction, and the subsequent impacts on land use and land cover vary by large geopolitical regions (Richards and Tucker, 1988).

For example, in *Latin America*, especially Amazonia, a phase of extraction and harvesting of timber plus initial colonization, is generally followed by the establishment of colonists with a greater access to capital. Competition to define or redefine the rules of land and capital access takes place (frequently involving violent conflict), and leads to winners and losers—those increasing land holdings and those pushed/pulled onwards to expanding the agricultural frontier further, where land is still cheap. Since cattle provides the largest economic rewards, given market conditions and/or government subsidies, for the winners, large-scale land conversion to pasture follows. This, in turn, drives up land prices, leading to further land consolidation (Schmink and Wood, 1992; Moran, 1993; Coomes, 1996; Faminow, 1998; Imbernon, 1999; Mendoza and Dirzo, 1999).

In contrast, "weak" nation states in *Central Africa* depend heavily on natural resources, including timber, to generate foreign revenue. De facto regulations of this industry are weak, owing to inadequate law enforcement and corruption, increasing the forest area logged and the related environmental impacts. Migrants follow logging roads, clearing land for food and commercial crops. The amount of land that cultivators clear and the length of their fallows, which determine patterns of regrowth, are tied to such socio-economic triggers as devaluation of the national currency, changes in market prices of agricultural commodities, contract farming, and social conflicts (Mertens et al., 2000).

Finally, states in *Southeast Asia* seek to enhance state revenues and socio-political stability in frontiers by launching large forest development projects, either timber extraction initiatives or transmigration to settlement schemes and plantations. It is not uncommon for authorities to fail to enforce timber concession regulations, exacerbating the damages in areas logged, and akin to the African case, prompting further spontaneous settlement. Alternatively, large-scale plantation and intensive agricultural projects increase migrant involvement with commercial cultivation, often at the expense of indigenous people living near the forest frontier, where land conflicts follow (Angelsen, 1995; Xu et al., 1999; Ramakrishnan et al., 2000).

## 3. Rangeland modifications

### 3.1. *Simplification: Rangelands are "natural" "climax" vegetation*

Rangelands are defined by the presence of grass and trees used by grazers or browsers, and encompass vegetation types ranging from complete grass cover, through woodlands with as much as 80% canopy cover, to pastures within dense forests. Despite advances in rangeland ecology, some management specialists hold to the misconception that rangelands are natural entities which, in the absence of human impact, would persist unchanging within climate epochs. Some rangelands are indeed largely edaphically or climatically determined (arid/xeric; coastal zone, alpine and wetland ecosystems). More generally, large areas of rangelands are maintained in their current state by the interaction of human and biophysical drivers (Solbrig, 1993; Sneath, 1998). Thus, human activities are commonly a functional part of these "semi-natural" ecosystems, and reducing or eliminating human use will trigger significant changes. Temperate and tropical rangelands are both highly dynamic and also resilient, moving through multiple vegetation states, either as successional sequences or by shifting chaotically in response to random interplay of human and biophysical drivers (Walker, 1993).

### 3.2. *Simplification: Rangeland has a natural 'carrying capacity' for livestock, and exceeding this causes degradation especially in tropical and subtropical zones*

This 'carrying capacity' is believed to derive from agro-ecological potential and to be relatively constant. The intrinsic variability of rangeland ecology, however, makes it difficult to distinguish directional change (such as loss of biodiversity or soil degradation) from readily reversible fluctuations, such that interpretations of "degradation" and "desertification" must be viewed cautiously (Sandford, 1983; Puigdefàbregas, 1998). Rangelands in arid or semi-arid tropical and subtropical zones are increasingly seen as non-equilibrium ecosystems. Modification in the biological productivity of these rangelands at the annual to decadal time scales is mainly governed by biophysical drivers (e.g., interannual rainfall variability, ENSO events), with stocking rates having less long-term effect on productive potential (Behnke et al., 1993). Less arid systems in tropical and subtropical areas are increasingly seen as governed by a combination of human and biophysical drivers, and may be more prone to being developed through intensification and conversion.

### 3.3. *The complex pathways of rangeland modification*

State policies throughout sub-Saharan Africa are framed under the assumption that pastoralists overstock rangelands, leading to degradation. The resulting management strategies aim to control, modify, and even obliterate traditional patterns of pastoralism, including the development of watering points or long-term exclusion of grazing (Ellis and Swift, 1988; Niamir-Fuller, 1998). Two common pathways follow. Weakened indigenous pastoral systems undermine local economies and resource institutions or precipitate urban migration with rural remittances, either of which may lead to land alienation and conversion, with concentration in the remaining areas, local overstocking and degradation. Alternatively, exclusion and reduced grazing lead to changes in species diversity, vegetation cover and plant production, with implications for biodiversity conservation and/or animal production. In wetter rangelands, reduced burning leads to increasing woodlands. Evidence indicates that grazing, rather than being inherently destructive, is necessary for the maintenance of tropical rangelands (Oba et al., 2000).

Rangeland dynamics in northern Europe over the last 2500–3000 years reveal a trajectory of change in some ways comparable to trends of intensification across the African Sahel today (Bassett and Zueli, 2000). Holocene climate change triggered the shift from migratory pastoralism to village formation, with associated winter fodder systems (hay meadows) complemented by large areas for summer grazing (Berglund, 1991). The presence of livestock increased soil nutrients around villages, improving agricultural production. Prevailing land tenure systems, which regulated land subdivision between generations, and population increase triggered land reforms. Agricultural intensification and mechanization from the mid 20th century removed the nutrient connection between arable lands and livestock, separating cultivated plains from mountain and forest areas used for grazing. Today, northern European rangelands, which also depend on grazing, are increasingly converted to intensive fodder production or forestry. The conversion and fragmentation of these temperate semi-natural rangelands leads to progressive loss of biodiversity, species connectivity, and means for recovery.

## 4. Agricultural intensification

### 4.1. *Simplification: Population growth drives unsustainable intensification in smallholder agriculture*

Agricultural intensification—defined as higher levels of inputs and increased output (in quantity or value) of cultivated or reared products per unit area and time—permitted the doubling of the world's food production from 1961 to 1996 with only a 10% increase in arable land globally (Tilman, 1999). Such achievements are viewed skeptically by observers contemplating the future of non-irrigated agriculture in the tropical world where intensification may be considered as environmentally untenable, owing to special biophysical constraints and socio-economic conditions that inhibit farmers' (especially smallholders') access to input factors. Rapidly developing land scarcity may trigger increase in cropping frequency unmatched by appropriate changes in inputs or management, resulting in a "stressed" system with stagnating or declining output (English, 1998;

Turner and Ali, 1996), abandoned "landesque" capital such as terraces, irrigation (Stone, 1998; Ramakrishnan, 1992), and land degradation. Although such negative trajectories of change are well documented, the more common response to land scarcity may be adaptation of the agricultural system to increase yield (Bray, 1986; Netting, 1993; Turner et al., 1993; Dasgupta et al., 2000). Such adjustments usually include both intensification within the subsistence sector and increasing commercial output (Guyer, 1997), as well as new strategies by households, including circulation, migration and off-farm employment. Various combinations of diversification sustain agricultural systems even under high population densities and climatic risk (Mortimore and Adams, 1999; Mortimore and Tiffen, 1994).

### 4.2. The multiple pathways of intensification

Three major, if interactive, pathways capture much of the intensification underway in agriculture. Intensification is triggered by *land scarcity* in economies not yet fully integrated in the market, and is usually linked to growth in population and its density, whether caused by natural increase, migration, incursion of non-agricultural land uses or institutional factors such as land tenure regime (Ostrom et al., 1999). Land scarcity changes land–labor ratios, driving up the intensity of cultivation and, where possible, shifting production toward the market and to higher value products. Such systems can be ecologically sustainable in the long run, but they tend to affect households differently, pushing some towards increased wage labor, impoverishment, or migration (Boyce, 1987; Coomes and Burt, 1997). Markets trigger commercial intensification of agriculture in a *commodification* pathway. Investments in crops or livestock modify the factors and value of production per hectare. Economic differentiation, wage labor, contract farming and other adjustments follow. This pathway is linked to external sources of demand and its sustainability is tied to the vagaries of the market. Collapses in product markets and/or subsidy programs supporting these markets trigger collapses or changes in production systems. Yet, incentives give rise to experimentation with new crops and products.

Significant land-use intensification can also be driven by *intervention,* usually in state-, donor-, or NGO-sponsored projects intended to promote development in a region or economic sector, usually through commercial agriculture for national and international markets that increase income for the participants and the state. This intensification pathway is vulnerable not only to markets, but to changes in government or donor policy, public sector financial constraints, and inefficient management or corruption (Altieri, 1999), especially as the scale of intervention increases and production is controlled from afar. Surprisingly, failed interventions often are followed by new initiatives that replicate similar weaknesses (Holling and Meffe, 1996). Intervention, market opportunities and cash crop production often attract in-migrants, thus creating interactions among the three pathways, in whose configuration the role of policy is critical, having either positive or negative effects.

## 5. Urbanization

### 5.1. Simplification: Urbanization is unimportant in global land-cover change

Urbanization as land cover, in the form of built-up or paved-over areas, occupies less than 2% of the earth's land surface (Grübler, 1994). Changes in the *area* of urban land per se, therefore, do not appear to be central to land-cover change. This claim appears to support a misconception that urbanization can be ignored in land change studies (Heilig, 1994). In reality, urbanization affects land change elsewhere through the transformation of urban-rural linkages. For example, urban inhabitants within the Baltic Sea drainage depend on forest, agriculture, wetland, lake and marine systems that constitute an area about 1000 times larger than that of the urban area proper (Folke et al., 1997). Given that urban life-styles tend to raise consumption expectations and that 60% of the world's population will be urban by 2025 (United Nations Population Fund, 1991), the rural–urban linkage or the urban "ecological footprint" is critical to land change assessments.

### 5.2. The major pathways of urban impacts on rural land cover

At least two broad urbanization pathways lead to different impacts on rural landscapes. In the *developed world*, large-scale urban agglomerations and extended peri-urban settlements fragment the landscapes of such large areas that various ecosystem processes are threatened. Ecosystem fragmentation, however, in peri-urban areas may be offset by urban-led demands for conservation and recreational land uses. In a different vein, economically and politically powerful urban consumers tend to be disconnected from the realities of resource production and largely inattentive to the impacts of their consumption on distant locales (Sack, 1992). Urbanization in the *less-developed world* outbids all other uses for land adjacent to the city, including prime croplands. Cities attract a significant proportion of the rural population by way of permanent and circulatory migration, and the wages earned in the city are often remitted by migrants to rural homelands, in some cases transforming the use of croplands and creating "remittance landscapes". Perhaps most importantly, this urbanization changes ways of life ultimately associated with demographic transitions, increasing expectations about consumption, and potentially a weakened understanding of production–consumption relationships noted for the well-developed world.

## 6. Globalisation as a unifying theme

The pathways of land-cover change described above are largely the result of cause-connection patterns operating at regional and national scales. Crosscutting these pathways are the many processes of "globalization" that amplify or attenuate the driving forces of land-use change by removing regional barriers and strengthening global at the expense of national connections. By globalization, we refer to worldwide interconnectedness of places and people through, for example, global markets, information and capital flows, and international conventions. Rapid land-use changes often coincide with the incorporation of a region into an expanding world economy. Global forces increasingly replace or rearrange the local factors determining land uses, building new, global cause-connection patterns in their place. Globalization, through global-scale linkages, disconnects the sources of demand from the location of production (Svedin, 1999). Market cultivation leads to species and varietal specialization, threatening local diversity in land use patterns. Globalisation also affects land use indirectly, e.g. through eco-labeling, information technologies leading to better forecasts on weather or market prices for farm management, or land monitoring using Earth observation satellites which provide control and global sanctioning (e.g., as in the case of forest fires in Indonesia).

Global markets increase complexity and uncertainty, raising concerns about risk impacts from global–local interplay of driving forces (Wilbanks and Kates, 1999). The same forces of globalization underly processes of tropical deforestation, e.g. through an expansion and liberalization of the markets for forest products, rangeland modifications, e.g. by the application to tropical regions of inappropriate land management systems designed elsewhere, agricultural intensification, e.g. through domestic and international capital flows leading to agricultural specialization, and urbanization, by the diffusion of the urban culture.

## 7. From simplicity to complexity . . . and generality

The analysis we have argued above shows how the rich array of local-level human-environment case studies can be used to create regional "generalities" of land-use and land-cover change that promise to improve understanding and modeling of critical themes in global change and sustainability studies. The implications of these pathways are significant for a number of broad themes that have captured the attention of researchers and policy-makers.

One such theme is the *IPAT* formulation [Impact (on environment or resource) = Population × Affluence × Technology (Ehrlich and Holdren, 1974)], which has gained sustained attention through its simplicity and elegance (Kates, 2000). Many social scientists, however, are wary of IPAT, for several reasons including the fact that interdependencies among P, A, and T make their separation problematic. *IPAT*-linked work also invokes a neo-Malthusian or ecocentric vision—closed system with inflexible limits—and a exogenous role for technology in determining these limits. The culprit in land degradation or poverty is seen to be the high rate of natural population growth in proximity to the place in question, and hence solutions are to be found in limiting population—rather than in changing consumption and behavioral patterns. Other research, in contrast, supports a Boserupian or anthropocentric view—open systems with flexible limits—and an endogenous role for technology. This view, to which a significant number of case studies lend support, interprets the role of population growth in the context of broader conditions, with potentially positive outcomes for welfare and the environment. This analysis shows that, at case study and regional level, the IPAT formulation is insufficiently sensitive to capture the diversity, variability and complexity of real-world situations.

Political economic explanations focus on differential power and access enforced by dominant social structures as the centerpiece of land-use change (Blaikie and Brookfield, 1987). The restricted options created by poverty drive inappropriate land use and degradation, while unchecked state and corporate concentration of wealth lead to "mega-development" and resource extraction projects that degrade the environment. In general, political economic formulations tend to assume that capitalist-based structures, compared to all others, exacerbate differences in power and access and, hence, land change. The significant environmental changes effected by non-capitalist structures, and to which the case study literature bears witness, are dismissed, as are those reinforcing conditions in which land redistribution alongside rapid population growth leads to shared poverty.

Case study evidence support the conclusion that the simple answers found in population growth, poverty, and infrastructure rarely provide an adequate understanding of land change. Rather, individual and social responses follow from changing economic conditions, mediated by institutional factors. Opportunities and constraints for new land uses are created by markets and policies, increasingly influenced by global factors. Extreme biophysical events occasionally trigger further changes. Various human-environment conditions react to and reshape the impacts of drivers differently, leading to specific pathways of land-use change. It is precisely these combinations that need to be conceptualized and used as the basis of land change explanations and models. Certain conditions appeared repeatedly in the case studies reviewed, including: weak state economies in forest frontiers; institutions in transition or absent in developing regions; induced innovation and intensification, especially in peri-urban and market accessible areas of developing regions; urbanized aspirations and income with differential rural impacts; new economic opportunities linked to new market outlets, changes in economic policies or capital investments; and inappropriate intervention giving rise to rapid modifications of landscapes and ecosystems.

These pathways indicate that land-use policies and projections of the future role of land-use change in Earth System dynamics must not only capture the complex socio-economic and biophysical drivers of land-use change but also account for the specific human-environment conditions under which the drivers of change operate. This recognition requires moving beyond some of the simplifications that persist in much of the current understanding of the causes of land-use and land-cover change. This does not preclude the development of a conceptually-based, land change science. Rather, it calls for advances that capture the generic qualities of both socio-economic and biophysical drivers as well as the place-based, human-environment conditions that direct land-use and land-cover change. Integration of natural and social sciences as well as recognition of the increasing role of global factors is required to meet the challenge.

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## References

Allen, J.C., Barnes, D.F., 1985. The causes of deforestation in developing countries. Annals of the Association of American Geographers 75 (2), 163–184.

Altieri, M.A., 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment 74, 19–31.

Anderson, L.E., 1996. The causes of deforestation in Brazilian Amazon. Journal of Environment and Development 5, 309–328.

Angelsen, A., 1995. Shifting cultivation and deforestation: a study from Indonesia. World Development 23, 1713–1729.

Angelsen, A., Kaimowitz, D., 1999. Rethinking the causes of deforestation: lessons from economic models. The World Bank Research Observer 14, 73–98.

Barraclough, S.L., Ghimire, K.B., 1996. Deforestation in Tanzania: beyond simplistic generalizations. The Ecologist 26 (3), 104–107.

Bassett, T.J., Zueli, K.B., 2000. Environmental discourses and the Ivorian savanna. Annals of the Association of American Geographers 90, 67–95.

Behnke, R., Scoones, I., Kerven, C., 1993. Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. Overseas Development Institute, London.

Berglund, B.E., 1991. The cultural landscape during 6,000 years in southern Sweden—the Ystad. Project. Ecol. Bull. No. 41, Copenhagen.

Blaikie, P., Brookfield, H., 1987. Land Degradation and Society. Routledge, London.

Boyce, J.K., 1987. Agrarian Impasse in Bengal: Institutional Constraints to Technological Change. Oxford Univ. Press, Oxford.

Bray, F., 1986. The Rice Economies: Technology and Development in Asian Societies. Blackwell, Oxford.

Chase, T.N., Pielke, R.A., Kittel, T.G.F., Nemani, R.R., Running, S.W., 1999. Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics 16, 93–105.

Committee on Global Change Research, 1999. Global Environmental Change: Research Pathways for the Next Decade. National Academy Press, Washington, DC.

Coomes, O.T., 1996. State credit programs and the peasantry under populist regimes: lessons from the APRA experience in the Peruvian Amazon. World Development 24, 1333–1346.

Coomes, O.T., Burt, G.J., 1997. Indigenous market-oriented agroforestry: dissecting local diversity in western Amazonia. Agroforestry Systems 37, 27–44.

Dasgupta, P., Levin, S., Lubchenco, J., 2000. Economic pathways to ecological sustainability. BioScience 50, 339–345.

Ehrlich, P., Holdren, J., 1974. The impact of population growth. Science 171, 1212–1217.

Ellis, J., Swift, D., 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. Journal of Rangeland Management 41, 450–459.

English, J., 1998. Malawi Impact Evaluation Report: The World Bank and the Agricultural Sector. World Bank, Washington, DC.

Fairhead, J., Leach, M., 1996. Misreading the African Landscape: Society and Ecology in a Forest-Savanna Mosaic. Cambridge Univ. Press, Cambridge.

Faminow, M.D., 1998. Cattle, Deforestation and Development in the Amazon: An Economic, Agronomic, and Environmental Perspective. CAB International, New York.

Folke, C., Jansson, Larsson, J., Costanza, R., 1997. Ecosystem appropriation by cities. Ambio 26, 167–172.

Geist, H.J., Lambin, E.F., 2001. What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational scale case study evidence. LUCC Report Series No. 4. University of Louvain, Louvain-la-Neuve.

Goldewijk, K., Battjes, J.J., 1997. A Hundred Year Database for Integrated Environmental Assessments. National Institute of Public Health and the Environment, Bilthoven.

Grübler, A., 1994. Technology. In: Meyer, W.B., Turner, B.L. II (Eds.), Changes in Land Use and Land Cover: A Global Perspective. Univ. of Cambridge Press, Cambridge, pp. 287–328.

Guyer, J.I., 1997. Diversity and intensity in the scholarship on African agricultural change. Review of Anthropology 26, 13–32.

Hecht, S.B., 1985. Environment, development, and politics: capital accumulation and the livestock sector in Amazonia. World Development 13 (6), 663–684.

Heilig, G.K., 1994. Neglected dimensions of global land-use change: reflections and data. Population and Development Review 20 (4), 831–859.

Holling, C.S., Meffe, G.K., 1996. Command and control and the pathology of natural resource management. Conservation Biology 10, 328–337.

Houghton, R.A., Hackler, J.L., Lawrence, K.T., 1999. The U.S. carbon budget: contribution from land-use change. Science 285, 574–578.

Imbernon, J.A., 1999. Comparison of the driving forces behind deforestation in the Peruvian and the Brazilian Amazon. Ambio 28, 509–513.

Intergovernmental Panel on Climate Change, 2000. Land use, land-use change, and forestry. Special Report. Cambridge Univ. Press, Cambridge.

Kasperson, J.X., Kasperson, R.E., Turner, B.L. II (Eds.), 1995. Regions at Risk: Comparisons of Threatened Environments. United Nations Univ. Press, Tokyo.

Kates, R.W., 2000. Population and consumption: what we know, what we need to know. Environment 42 (3), 10–19.

Lambin, E.F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner, B.L. II, Vogel, C., 1999. Land-use and land-cover change (LUCC): Implementation strategy. IGBP Report No. 48, IHDP Report No. 10, Stockholm, Bonn.

Loveland, T.R., Zhu, Z., Ohlen, D.O., Brown, J.F., Reed, B.C, Yang, L.M., 1999. An analysis of the IGBP global land-cover characterization process. Photogrammetric Engineering and Remote Sensing 65 (9), 1021–1032.

Mather, A.S., Needle, C.L., 2000. The relationships of population and forest trends. The Geographical Journal 166 (1), 2–13.

Mendoza, E., Dirzo, R., 1999. Deforestation in Lacandonia (southeast Mexico): evidence for the declaration of the northernmost tropical hot-spot. Biodiversity and Conservation 8, 1621–1641.

Mertens, B., Sunderlin, W., Ndoye, O., Lambin, E.F., 2000. Impact of macro-economic change on deforestation in South Cameroon: integration of household survey and remotely-sensed data. World Development 28, 983–999.

Moran, E.F., 1993. Deforestation and land use in the Brazilian Amazon. Human Ecology 21, 1–21.

Mortimore, M., Adams, W.M., 1999. Working the Sahel: Environment and society in Northern Nigeria. Routledge, London.

Mortimore, M., Tiffen, M., 1994. Population growth and a sustainable environment. Environment 36, 10–17.

Netting, R.M., 1993. Smallholders, Householders, Farm Families and The Ecology of Intensive, Sustainable Agriculture. Stanford Univ. Press, Stanford.

Niamir-Fuller, M., 1998. The resilience of pastoral herding in Sahelian Africa. In: Berkes, F., Folke, C. (Eds.), Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge Univ. Press, Cambridge, pp. 250–284.

Oba, G., Stenseth, N.C., Lusigi, W.J., 2000. New perspectives on substainable grazing management in arid zones of sub-Saharan Africa. BioScience 50, 35–51.

Ostrom, E., Burger, J., Field, C.B., Noorgaard, R.B., Policansky, D., 1999. Revisiting the commons: Local lessons, global challenges. Science 284, 278–282.

Puigdefàbregas, J., 1998. Ecological impacts of global change on drylands and their implications for desertification. Land Degradation & Development 9, 383–392.

Ramakrishnan, P.S., 1992. Shifting agriculture and sustainable development: an interdisciplinary study from North-Eastern India. Parthenon Publ., Carnforth.

Ramakrishnan, P.S., Chandrashekara, U.M., Elouard, C., Guilmoto, C.Z., Maikhuri, R.K., Rao, K.S., Sankar, S., Saxena, K.G. (Eds.), 2000. Mountain Biodiversity, Land Use Dynamics, and Traditional Ecological Knowledge. Oxford and IBH Publ., New Delhi, Calcutta.

Ramankutty, N., Foley, J.A., 1999. Estimating historical changes in global land cover: Croplands from 1700 to 1992. Global Biogeochemical Cycles 13, 997–1027.

Richards, J.F., Tucker, R.P. (Eds.), 1988. World Deforestation in the Twentieth Century. Duke Univ. Press, Durham.

Rudel, T.K., 1993. Tropical Deforestation. Small Farmers and Land Clearing in the Ecuadorian Amazon. Columbia University Press, New York.

Rudel, T., Roper, J., 1996. Regional patterns and historical trends in tropical deforestation, 1976–1990: a qualitative comparative analysis. Ambio 25, 160–166.

Sack, R.D., 1992. Place, Modernity and the Consumer's World. Johns Hopkins Press, Baltimore.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Biodiversity: global biodiversity scenarios for the year 2100. Science 287, 1770–1774.

Sandford, S., 1983. Management of Pastoral Development in the Third World. Wiley, Chichester.

Schmink, M., Wood, C.H., 1992. Contested Frontiers in Amazonia. Columbia University Press, New York.

Sneath, D., 1998. Ecology: State policy and pasture degradation in inner Asia. Science 281, 1147–1148.

Solbrig, O., 1993. Ecological constraints to savanna land use. In: Young, M.D., Solbrig, O.T. (Eds.), The World's Savannas: Economic Driving Forces, Ecological Constraints and Policy Options for Sustainable Land Use. Man and the Biosphere Series 12. UNESCO & Parthenon Publ., Paris.

Stone, G.D., 1998. Keeping the home fires burning: the changed nature of householding in the Kofyar homeland. Human Ecology 26, 239–265.

Svedin, U., 1999. Urban and non-urban environmental policies as expressions of changed perceptions about ways of handling societal change. In: Lindqvist, C., Wallenius, L.-L. (Eds.), Globalization and Its Impact—On Chinese and Swedish Society. Forskningsrdsnmnden, Stockholm, pp. 231–242.

Tilman, D., 1999. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Proceedings of the National Academy of Sciences of the United States of America, Vol. 96, pp. 5995–6000.

Tolba, M.K., El-Kholy, O.A. (Eds.), 1992. The World Environment 1972–1992: Two Decades of Challenge. Chapman & Hall, London.

Turner, B.L. II, Ali, A.M.S., 1996. Induced intensification: Agricultural change in Bangladesh with implications for Malthus and Boserup. Proceedings of the National Academy of Sciences of the United States of America, Vol. 93, pp. 14984–14991.

Turner, B.L. II, Hyden, G., Kates, R.W. (Eds.), 1993. Population Growth and Agricultural Change in Africa. Univ. Press of Florida, Gainesville.

Turner, B.L. II, Clark, W.C., Kates, R.W., Richards, J.F., Mathews, J.T., Meyer, W.B. (Eds.), 1990. The Earth as Transformed by Human Action: Global and Regional Changes in the

Biosphere Over the Past 300 Years. Cambridge Univ. Press, Cambridge.
United Nations Population Fund, 1991. Population, Resources and the Environment: The Critical Challenges. United Nations, New York.
Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of earth's ecosystems. Science 277, 494–499.
Walker, B.H., 1993. Rangeland ecology: understanding and managing change. Ambio 22, 80–87.
Wilbanks, T.J., Kates, R.W., 1999. Global change in local places: how scale matters. Climatic Change 43, 601–628.
Xu, J., Fox, J., Xing, L., Podger, N., Leisz, S., Xihui, A., 1999. Effects of swidden cultivation, state policies, and customary institutions on land cover in a Hani village, Yunnan, China. Mountain Research and Development 19 (2), 123–132.

## ACT Publications 2000

No. 00-01
E. F. Moran. The Unity of Theory and Practice in Anthropology: Rebuilding a Fractured Synthesis. C.E. Hill and M. L. Baba (eds.) Arlington, VA. In *NAPA Bulletin 18*, 2000, (pp 132-146).

No. 00-02
E. F. Moran, Brondizio, E.S., Tucker, J., Silva-Forsberg, M.C., Falesi, I., and S. McCracken. Strategies for Amazonian Forest Restoration: Evidence for Afforestation in Five Regions of the Brazilian Amazon. A. Hill (ed.). London. In *Amazonia at the Crossroads* (pp. 129-149), 2000.

No. 00-03
Walker, R., E. Moran, and L. Anselin. Deforestation and Cattle Ranching in the Brazilian Amazon: External Capital and Household Processes. *World Development* 28(4):683-699.

No. 00-04
Moran, E. F., Brondizio E. S., Tucker, J. M., Silva-Forsberg, M. C., McCracken, S., and Falesi, I. Effects of soil fertility and land-use on forest succession in Amazonia. *Forest Ecology and Management* 139(2000): 93-108.

No. 00-05
M. Batistella, E. Brondizio, and E. Moran. Comparative Analysis of Landscape Fragmentation in Rondônia, Brazilian Amazon. *International Archives of Photogrammetry and Remote Sensing*. Vol. XXXIII, Part B7. Amsterdam 2000