Proximate Causes and Underlying Driving Forces of Tropical Deforestation

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One of the primary causes of global environmental change is tropical deforestation, but the question of what factors drive deforestation remains largely unanswered (NRC 1999). Various hypotheses have produced rich arguments, but empirical evidence on the causes of deforestation continues to be largely based on cross-national statistical analyses (Bilsborrow 1994, Brown and Pearce 1994, Williams 1994, Painter and Durham 1995, Sponsel et al. 1996, Murali and Hedge 1997, Rudel and Roper 1997, Fairhead and Leach 1998). In some cases, these analyses are based on debatable data on rates of forest cover change (Palo 1999). The two major, mutually exclusive—and still unsatisfactory—explanations for tropical deforestation are single-factor causation and irreducible complexity. On the one hand, proponents of single-factor causation suggest various primary causes, such as shifting cultivation (Amelung and Diehl 1992, Myers 1993, Rerkasem 1996, Ranjan and Upadhyay 1999) and population growth (Allen and Barnes 1985, Amelung and Diehl 1992, Cropper and Griffiths 1994, Ehrhardt-Martinez 1998, Mather and Needle 2000). On the other hand, correlations between deforestation and multiple causative factors are many and varied, revealing no distinct pattern (Rudel and Roper 1996, Bawa and Dayanandan 1997, Mather et al. 1998, Angelsen and Kaimowitz 1999).

In addition to chronicling these attempts to identify general causes of deforestation through global-scale statistical analyses, the literature is rich in local-scale case studies investigating the causes and processes of forest cover change in specific localities. Our aim with this study is to generate from local-scale case studies a general understanding of the proximate causes and underlying driving forces of tropical deforestation while preserving the descriptive richness of these studies. Proximate causes are human activities or immediate actions at the local level, such as agricultural expansion, that originate from intended land use and directly impact forest cover. Underlying driving forces are fundamental social processes, such as human population dynamics or agricultural

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policies, that underpin the proximate causes and either operate at the local level or have an indirect impact from the national or global level.

We analyzed the frequency of proximate causes and underlying driving forces of deforestation, including their interactions, as reported in 152 subnational case studies. We show that tropical deforestation is driven by identifiable regional patterns of causal factor synergies, of which the most prominent are economic factors, institutions, national policies, and remote influences (at the underlying level) driving agricultural expansion, wood extraction, and infrastructure extension (at the proximate level). Our findings reveal that prior stud-

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ies have given too much emphasis to population growth and shifting cultivation as primary causes of deforestation.

Data analysis

Case studies of net losses of tropical forest cover ($n = 152$) were analyzed to determine whether the proximate causes and underlying driving forces of tropical deforestation fall into any patterns. Study areas range from a community to a multi-province area, and cases span time periods from 1880 to 1996, with 1940 to 1990 being the most frequently covered period. The 152 cases of tropical deforestation were taken from 95 articles published in 40 journals covered by the citation index of the Institute for Scientific Information (Geist and Lambin 2001). The criteria for selecting studies were the following: quantification of the rates of forest-cover change; net loss of forest cover during at least part of the study period; investigation method based on quantitative data or in-depth field investigations; consideration of clearly named factors as potential causes of deforestation, including basic features of the socioeconomic setting and the natural resource endowment; and absence of obvious disciplinary bias. We assumed that each study revealed the actual causes of deforestation in the study area. Therefore, our comparative analysis of case studies evaluates which causal patterns leading to deforestation are most often found in different tropical regions.

Four broad clusters of proximate causes were identified: agricultural expansion, wood extraction, infrastructure extension, and other factors. Each land use category was further subdivided; for example, agricultural expansion was divided into permanent cultivation, shifting cultivation, cattle ranching, and colonization (Figure 1). Underlying driving forces were categorized into five broad clusters: demographic, economic, technological, policy and institutional, and cultural factors. Each was further subdivided into specific factors; for example, cultural or sociopolitical factors were partitioned into public attitudes, values and beliefs, and individual or household behavior (Figure 1; Ledec 1985, Lambin 1994, Ojima et al. 1994, Turner et al. 1995, Lambin 1997, Contreras-Hermosilla 2000).

Causal factors were quantified by determining the most frequent proximate and underlying factors in each case. The major interactions and feedback processes between these factors were also identified to reveal the systems dynamics that commonly lead to deforestation. Three modes of causation were distinguished: single-factor causation (i.e., one individual underlying factor driving one or more proximate factors), chain-logical causation (i.e., several interlinked factors in combination leading to deforestation), and concomitant occurrence (i.e., independent, separate operation of factors causing deforestation). Results were broken down by broad geographical regions (Asia, $n = 55$; Africa, $n = 19$; Latin America, $n = 78$). They are given in order of decreasing importance, with factors occurring in less than 25% of the cases not reported.
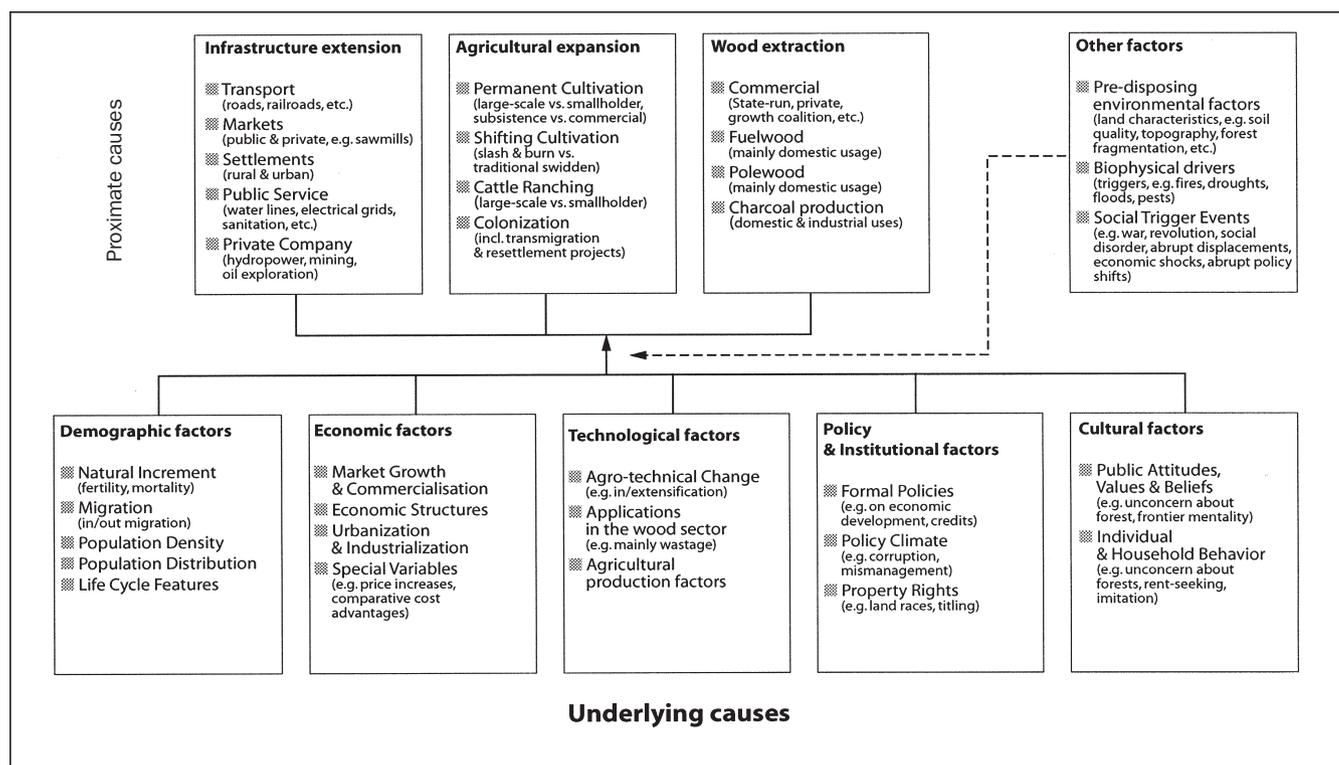

Figure 1. Causes of forest decline. Five broad clusters of underlying driving forces (or fundamental social processes) underpin the proximate causes of tropical deforestation, which are immediate human actions directly impacting forest cover.

Proximate causes

At the proximate level, tropical deforestation is best explained by multiple factors rather than by single variables. Dominating the broad clusters of proximate causes is the combination of agricultural expansion, wood extraction, and infrastructure expansion, with clear regional variations (Table 1). The tables presented here provide a breakdown of proximate causes and underlying driving forces by broad geographical regions (or continents). They show the absolute number as well as the relative percentage of the frequency of causative variables reported in the case studies. Tables 1 and 3 give only the broad clusters of proximate causes and underlying driving forces, and Tables 2 and 4 provide a detailed breakdown of the broad clusters by specific factors. Only the frequency of modes of causation (single or multifactorial) by broad clusters of proximate and underlying variables (Tables 1 and 3) shows cumulative percentages of cases, adding up to 100%. The relative percentages of the frequency of occurrence of specific factors (Tables 2 and 4) do not add up to 100%, as multiple counts exist because of causal factor synergies (discussed later).

Agricultural expansion is, by far, the leading land-use change associated with nearly all deforestation cases (96%). It includes, with more or less equal frequencies, forest conversion for permanent cropping, cattle ranching, shifting cultivation, and colonization agriculture (Table 2). Only permanent agriculture and shifting cultivation display low geo-graphical variation; that is, regional values for permanent cultivation in Asia, Africa, and Latin America are close to the "global" value (i.e., 44%, 53%, and 50%, respectively, compared with a global 48%), similarly for shifting cultivation (i.e., 44%, 42%, and 40%, respectively, compared with a global 41%). Further subdivisions reveal striking regional differences, however. In permanent cultivation, the expansion of food-crop cultivation for subsistence is three times more frequently reported than the expansion of commercial farming (less than 25% for all regions). In shifting cultivation, cases of deforestation driven by slash-and-burn agriculture are more widespread in upland and foothill zones of Asia than elsewhere, whereas when practiced by colonizing migrant settlers in Latin America, it is mainly limited to lowland areas. Pasture creation for cattle ranching is a striking cause of deforestation reported almost exclusively for humid lowland cases from mainland South America.

Commercial wood extraction is frequent in both mainland and insular Asia, whereas in Africa the harvesting of fuel wood and poles by individuals for domestic uses dominates cases of deforestation associated with wood extraction. Among all forms of infrastructure expansion, road construction is by far most frequently reported, mainly in both lowland and mountain cases of Latin America. Predisposing environmental factors such as land characteristics (soil quality, topography) or trigger events, whether biophysical (droughts,

Table 1. Frequency of broad clusters of proximate causes in tropical deforestation.

	All cases (n = 152)			Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	cum (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Single-factor causation									
Agricultural expansion	6	4	4	2	4	1	5	3	4
Wood extraction	2	1	5	0	–	2	11	0	–
Infrastructure expansion	1	1	6	0	–	0	–	1	1
Other[a]	0	–	–	0	–	0	–	0	–
Two-factor causation									
Agro-wood[b]	22	15	20	12	22	2	11	8	10
Agro-infra[c]	30	20	40	3	6	2	11	25	32
Agro-other	5	3	43	1	2	3	16	1	1
Wood-infra	1	1	44	0	–	0	–	1	1
Wood-other	1	1	45	0	–	1	6	0	–
Three-factor causation									
Agro-wood-infra	38	25	70	21	38	2	11	15	19
Agro-wood-other	6	4	74	4	7	1	5	1	1
Agro-infra-other	8	5	79	0	–	0	–	8	10
Wood-infra-other	1	1	80	0	–	0	–	1	1
Four-factor causation									
All	31	20	100	12	22	5	26	14	18
Total	152	100	–	55	100	19	100	78	100

Note: abs, absolute number; rel, relative percentages; cum, cumulative percentages. Relative percentages may not total 100 because of rounding.
a. "Other" refers to predisposing environmental factors, such as land characteristics and social as well as biophysical trigger events.
b. Agro, agricultural expansion; wood, wood extraction.
c. Infra, infrastructure expansion.

floods) or social (mainly wars), are reported to influence deforestation in one-third of the cases.

Among the detailed categories of proximate causes for all regions, the extension of overland transport infrastructure, followed by commercial wood extraction, permanent cultivation, and cattle ranching, are the leading proximate causes of deforestation. Contrary to widely held views, case study evidence suggests that shifting cultivation is not the primary cause of deforestation.

Underlying driving forces

At the underlying level, tropical deforestation is also best explained by multiple factors and drivers acting synergistically rather than by single-factor causation, with more than one-third of the cases being driven by the full interplay of economic, institutional, technological, cultural, and demographic variables (Table 3).

Economic factors are prominent underlying forces of tropical deforestation (81%). Commercialization and the growth of mainly timber markets (as driven by national and international demands) as well as market failures are frequently reported to drive deforestation (Table 4). Economic variables such as low domestic costs (for land, labor, fuel, or timber), product price increases (mostly for cash crops), and the ecological footprint of remote urban-industrial centers underpin about one-third of the cases each, whereas the requirement to generate foreign exchange earnings at a national level intervenes in a quarter of the cases. With few exceptions, factors related to economic development through a growing cash economy show little regional variation and, thus, con-

stitute a robust underlying force of deforestation. A number of case studies describe a process of frontier colonization with a sequence of poverty- and capital-driven deforestation (Rudel and Roper 1997). Poverty-driven deforestation refers to the ecological marginalization of farmers who have lost their resource entitlements, and capital-driven deforestation refers to public or private investments to develop the frontier for political, economic, or social reasons. Underlying 42% of the cases each, both processes overlap considerably.

Institutional factors also drive many cases of deforestation (78%). These factors mainly include formal pro-deforestation measures such as policies on land use and economic development as related to colonization, transportation, or subsidies for land-based activities. Land tenure arrangements and policy failures (such as corruption or mismanagement in the forestry sector) are also important drivers of deforestation. Though much discussed as a general cause of deforestation (e.g., Deacon 1994, Mendelsohn and Balick 1995), property rights issues are mainly a characteristic of Asian cases and tend to have ambiguous effects upon forest cover: insecure ownership, quasi-open access conditions, maladjusted customary rights, as well as the legalization of land titles, are all reported to influence deforestation in a similar manner.

Among technological factors (70%), important processes affecting deforestation are agrotechnological change, with agricultural intensification having no distinct impact separate from agricultural expansion, and poor technological applications in the wood sector (leading to wasteful logging practices).

Table 2. Frequency of specific proximate causes in tropical deforestation.

	All cases (n = 152)		Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Agricultural expansion	146	96	55	100	16	84	75	96
Permanent cultivation	73	48	24	44	10	53	39	50
Subsistence agriculture	61	40	20	36	10	53	31	40
Cattle ranching	70	46	3	6	3	16	64	82
Shifting cultivation	63	41	24	44	8	42	31	40
Swidden agriculture	46	30	24	44	7	37	15	19
Colonization[a]	61	40	23	42	4	21	34	44
Infrastructure expansion	110	72	36	66	9	47	65	83
Transport extension	97	64	26	47	9	47	62	80
Roads	93	61	25	46	9	47	59	76
Settlement/market extension	41	27	12	22	3	16	26	33
Wood extraction	102	67	49	89	13	68	40	51
Commercial (for trade)	79	52	43	78	5	26	31	40
Fuel wood (for domestic uses)	42	28	18	33	10	53	14	18
Other factors[b]	52	34	17	31	10	53	25	32

Note: Multiple counts possible; percentages relate to the total of all cases for each category; abs, absolute number; rel, relative percentages; cum, cumulative percentages. Relative percentages may not total 100 because of rounding.

a. Including transmigration and resettlement.

b. Predisposing environmental factors such as land characteristics and social or biophysical trigger events.

Table 3. Frequency of broad underlying driving forces in tropical deforestation.

	All cases (n = 152)			Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	cum (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Single-factor causation									
Economic (econ)	13	9	9	0	–	0	–	13	17
Institutional (inst)	4	3	12	0	–	1	5	3	4
Technological (tech)	0	–	12	0	–	0	–	0	–
Cultural (cult)	0	–	12	0	–	0	–	0	–
Demographic (pop)	0	–	12	0	–	0	–	0	–
Two-factor causation									
Pop-econ	5	3	15	0	–	3	16	2	3
Pop-tech	4	3	17	2	4	1	6	1	1
Pop-inst	1	1	18	0	–	0	–	1	1
Pop-cult	1	1	18	0	–	0	–	1	1
Econ-tech	1	1	19	0	–	0	–	1	1
Econ-inst	5	3	22	0	–	0	–	5	6
Inst-cult	5	3	26	4	7	0	–	1	1
Three-factor causation									
Pop-econ-tech	5	3	29	0	–	4	21	1	1
Pop-econ-inst	1	1	30	1	2	0	–	0	–
Pop-econ-cult	2	1	31	0	–	1	5	1	1
Pop-tech-inst	4	3	34	1	2	1	5	2	3
Econ-tech-cult	1	1	34	0	–	0	–	1	1
Econ-inst-cult	6	4	38	0	–	0	–	6	8
Tech-inst-cult	5	3	42	5	9	0	–	0	–
Four-factor causation									
Pop-econ-tech-inst	8	5	47	5	9	2	11	1	1
Pop-econ-tech-cult	1	1	47	0	–	1	5	0	–
Pop-econ-inst-cult	2	1	49	1	2	0	–	1	1
Pop-tech-inst-cult	5	3	52	4	7	0	–	1	1
Econ-tech-inst-cult	19	13	64	12	22	0	–	7	9
Five-factor causation									
All	54	36	100	20	36	5	26	29	37
Total	152	100	–	55	100	19	100	78	100

Note: abs, absolute number; rel, relative percentages; cum, cumulative percentages. Relative percentages may not total 100 because of rounding.

Cultural or sociopolitical factors (66%) are reported to underlie mainly economic and policy forces in the form of attitudes of public unconcern towards forest environments. These factors also shape the rent-seeking behavior of individual agents causing deforestation.

Among demographic factors (61%), only in-migration of colonizing settlers into sparsely populated forest areas, with the consequence of increasing population density there, shows a notable influence on deforestation. It tends to feature African and Latin American rather than Asian cases. Contrary to a common misconception, population increase due to high fertility rates is not a primary driver of deforestation at a local scale, over a time period of a few decades, as it intervenes in 8% of the cases only and is always combined with other factors.

Interactions and feedbacks

Not only are multiple causal factors at work, but their interactions also lead to deforestation, which is why it is important to understand the systems dynamics (Figure 2). Our analysis reveals that, in most cases, three to four underlying causes are driving two to three proximate causes. A frequent pattern of causal interaction stems from the necessity for road construction that is associated with wood extraction or agricultural expansion, which is mostly driven by policy and institutional factors but also by economic and cultural factors. Pro-deforestation state policies aimed at land use and economic development (e.g., credits, low taxation, incentives for cash cropping, legal land titling) lead to the expansion of commercial crops and pastures in combination with an extension of the road network. Another pattern, seen mostly in Africa, comes from insecure ownership related to uncertainties of land tenure, which drives the shift from communal to private property and underlies many cases in which traditional shifting cultivation is a direct cause of deforestation. Policies facilitating the establishment of state agricultural and forestry plantations lead to deforestation in both insular and continental Asia. Agricultural colonization in Latin America is

Table 4. Frequency of specific underlying driving forces in tropical deforestation.

	All cases (n = 152)		Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Economic factors	123	81	39	71	16	84	68	87
Market growth/commercialization	103	68	30	55	15	79	58	74
Sectoral market growth[a]	78	51	23	42	13	68	42	54
Demand/consumption[b]	69	45	24	44	13	68	32	41
Market failures	52	34	22	40	6	32	24	31
Urban-industrial growth	58	38	23	42	5	26	30	39
Industrialization	43	28	21	38	1	5	21	27
Foreign exchange[c]	38	25	16	29	5	26	17	22
Special variables[d]	48	32	9	16	5	26	34	44
Institutional/policy factors	119	78	53	96	9	47	57	73
Formal policies	105	69	46	84	7	37	52	67
On land development	60	40	28	51	5	26	27	35
On economic growth[e]	51	34	22	40	5	26	24	31
On credits/subsidies	39	26	11	20	1	5	27	35
Property rights issues[f]	67	44	33	60	5	26	29	37
Policy failures[g]	64	42	31	56	1	5	32	41
Mismanagement	38	25	13	24	1	5	24	31
Technological factors	107	70	49	89	14	74	44	56
Agrotechnological change[h]	70	46	28	51	8	42	34	44
Production changes	50	33	17	31	5	26	28	36
Wood sector related[i]	69	45	39	71	8	42	22	28
Agriculture related	42	28	22	40	4	21	16	21
Cultural/sociopolitical factors	101	66	46	84	7	37	48	62
Public attitudes, values, beliefs	96	63	45	82	5	26	46	59
Public unconcern[j]	66	43	25	46	3	16	38	49
Missing basic values	55	36	33	60	2	11	20	26
Individual/household behavior	80	53	38	69	6	32	36	46
Situation specific[k]	74	49	36	66	5	26	33	42
Unconcern by individuals[l]	48	32	20	36	4	21	24	31
Demographic factors[m]	93	61	34	62	18	95	41	53
In-migration	58	38	12	22	9	47	37	47
Growing population density	38	25	12	22	6	32	20	26

Note: Multiple counts possible; percentages relate to the total of all cases in each category; abs, absolute number; rel, relative percentages; cum, cumulative percentages. Relative percentages may not total 100 because of rounding.

  a. Growth of markets for wood (e.g., timber products) 29%, agricultural products (e.g., food) 29%, and minerals 15% (e.g., oil energy).

  b. Demand for wood (e.g., processed timber) 32% and agricultural products (e.g., food) 18%.

  c. Generation of foreign exchange earnings.

  d. Low cost conditions (production factors) and price changes (increases and decreases).

  e. Especially agricultural and infrastructure development policies.

  f. "Land races," land tenure insecurity, quasi open access conditions, maladjusted customary rights, titling/legalization, low empowerment of local user groups.

  g. Corruption, lawlessness, clientelism, and the operation of vested interests and "growth coalitions," besides mismanagement or poor performance.

  h. Land use intensification and extension, besides changes in market vs. subsistence orientation, in intensity of labor vs. capital used, and in holding size (productional changes).

  i. Poor logging performance, wastage in timber processing, and poor domestic or industrial furnace performance.

  j. Dominant frontier mentality, prevailing attitudes of nation-building, modernization, and development, and low (public) morale.

  k. Mainly rent-seeking behavior (35%).

  l. Unconcern about the forest environment as reflected in increasing levels of demand, aspiration, and consumption, commonly associated with increased income.

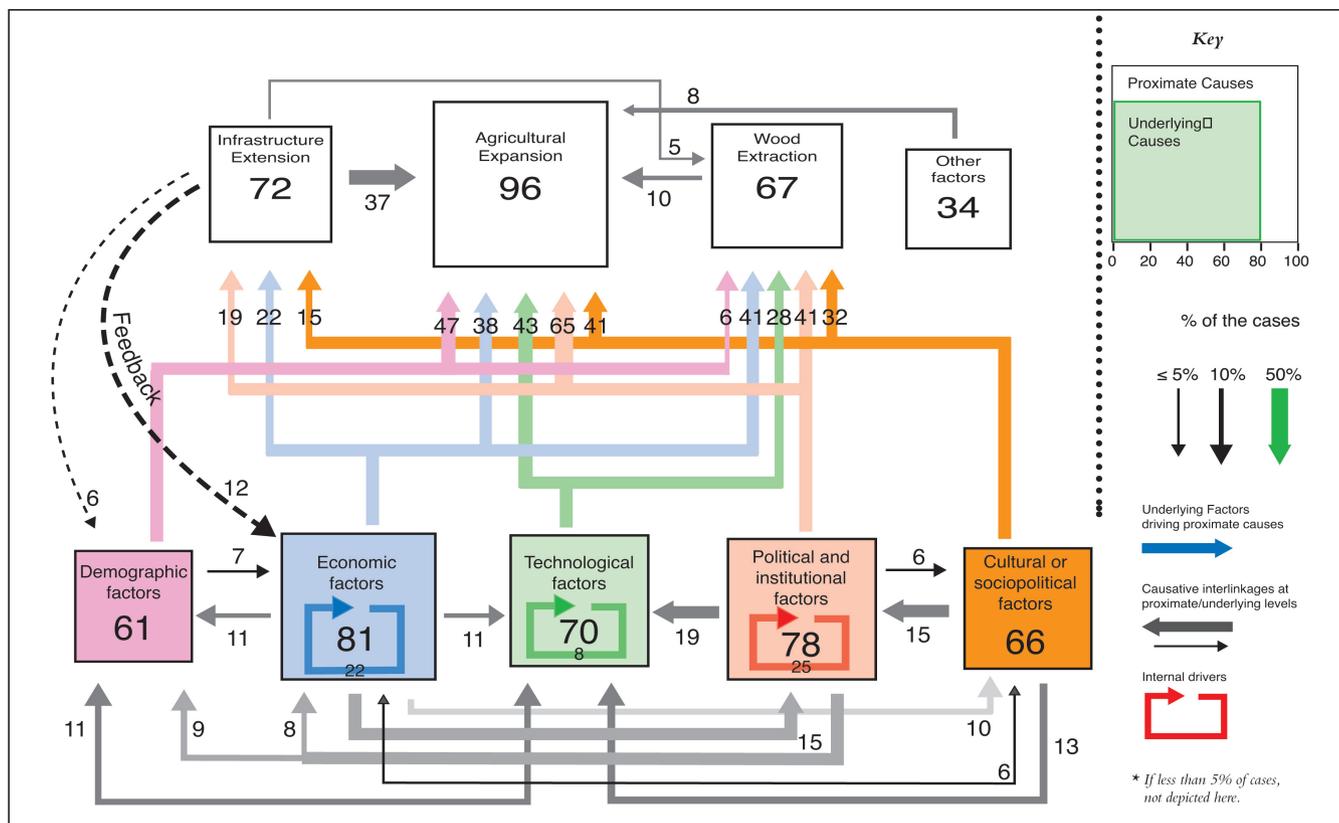 m. Including natural increment, spatial distribution, and life cycle features.

Figure 2. Causative pattern of tropical deforestation (n = 152 cases). Systems dynamics commonly lead to tropical deforestation. No single or key variable, such as population growth or shifting cultivation, unilaterally impacts forest cover change; synergies between proximate causes and underlying (social) driving forces best explain tropical forest cover losses. A recurrent set of mainly economic, political, and institutional driving forces underpins proximate causes, such as agricultural expansion, infrastructure extension, and wood extraction, leading to deforestation. Though some investigators have claimed irreducible complexity is the explanation, distinct regional patterns exist.

often favored by land policies that are directed towards deregulation of land access, transfer of public forest land to private holdings, and state regulations in favor of large individual land holdings.

Policy, institutional, and economic factors are also driving wood extraction. Cases of deforestation related to both private and state-run timber logging, especially in Asia, are almost exclusively driven by the liberal granting of concessions, development projects, and state claims for logging areas, in conjunction with corruption and poor implementation of forestry rules.

In-migration and, to a much lesser degree, natural population growth drive the expansion of cropped land and pasture in 47% of the cases in Africa and Latin America (22% in Asia), concomitantly with other underlying drivers. The extension of permanently cropped land for subsistence farming to meet the needs of a growing population is reported particularly for African cases. Expansion of pastures emerges exclusively from mainland South American cases, in association with processes of both planned colonization and spontaneous settlement by colonist agriculturalists.

Some feedbacks amplify the process of deforestation. The most frequent feedback identified is that from road construction and the creation of new settlements in a frontier area, which work upon economic factors such as the growth of wood and food markets. The development of commercialization induces further deforestation and agricultural modernization, mainly in frontier regions of the Amazon lowlands and in southeast Asia. Shifting cultivators turn into sedentary cash croppers and permanently settled subsistence farmers who respond to market signals.

Conclusion

Evidence from empirical case studies that identify both proximate causes and underlying forces of tropical deforestation suggests that no universal link between cause and effect exists. Rather than providing support for dominant theories of global deforestation (neoclassical, impoverishment, political ecology), analysis of these studies shows that tropical forest decline is determined by different combinations of various proximate causes and underlying driving forces in varying geographical and historical contexts. Some of these combinations are robust geographically (such as the development

of market economies and the expansion of permanently cropped land for food), whereas most of them are region specific. The observed causal factor synergies challenge single-factor explanations that put most of the blame of deforestation upon shifting cultivators and population growth (caused by natural increment). Rather, our analysis reveals that, at the underlying level, public and individual decisions largely respond to changing, national- to global-scale economic opportunities and/or policies, as mediated by local-scale institutional factors, and that, at the proximate level, regionally distinct modes of agricultural expansion, wood extraction, and infrastructure extension prevail in causing deforestation. As a major implication, case study–based evidence reveals that no universal policy for controlling tropical deforestation can be conceived. Rather, a detailed understanding of the complex set of proximate causes and underlying driving forces affecting forest cover changes in a given location is required prior to any policy intervention.

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