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Explaining the Causes of Deforestation with the Hyde Model (A Conceptual Framework)

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Abstract

Using the Hyde Model of forest land use change and tools of systems analysis, this paper builds a conceptual framework to analyze causes of deforestation. It identifies demand for forest land and resources as the underlying driver of deliberate deforestation. It distinguishes between determinants of demand for forest land/resources and direct causes of deforestation. Demand is an indirect cause which can only lead to deforestation through its effect on other factors (direct causes). The process of deforestation is complex—the outcome of the interplay of different causative factors in which one or a few dominate. The determinants of deforestation are not static as the combinations of factors that cause deforestation change over time and space.

Acknowledgments

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About the Author

Genesis Yengoh completed his undergraduate studies in geography at the University of Yaounde 1, Cameroon. In 2007, he received a Master of Science degree at Lund University in Environmental and Sustainability Sciences where he is currently working.

He has been working as a modeler with projects centered around building and using dynamic simulation models to develop policies in agricultural resource use and give advice on sustainable practices; applying models of land use and economic behavior to agricultural changes and developments; and advising agricultural companies on costs and benefits of options in sustainable agriculture.

His current research interests include the use of geographical information systems and dynamic systems modeling in natural resource management, sustainability analysis, and the integrated study of human-nature relationships in tropical forest ecosystems.

Explaining the Causes of Deforestation with the Hyde Model (A Conceptual Framework)

Genesis Tambang Yengoh

1 Introduction

Though trends in the evolution of the world's forest area indicate a general decline over several centuries, the rate of decline over the last half of the twentieth century has been of particular concern. Deforestation rates have not been uniform over the entire globe. Different regions have witnessed different rates of deforestation at different times in history. In recent years, the phenomenon seems to have settled in the tropical regions of the world (Bryant *et al.,* 1997; WRI, 2000; Matthews *et al.,* 2000; FAO, 1990, 2001a, b, 2003). The United Nations Food and Agriculture Organization (FAO, 2001a) estimated that the annual rate of deforestation in developing countries stood at about 14.2 million hectares (ha) between 1990 and 2000 within a global total of 14.6 million ha. In its Forest Resources Assessment (FAO, 2005) it was reported that today about 4 billion ha of forest exist on the earth (approximately 30.3% of the total land area). Global forest area per capita stood at 0.62 ha with more than half of the world's forest area found in the Russian Federation (one of ten countries which possess two-thirds of global forest cover); and that 64 countries have less than 10% of their total land area forested (predominantly in North Africa and West Asia).

Of equal importance were the figures given on the state of deforestation: each year about 13 million ha of the world's forests are lost due to deforestation. While stating that 37 countries were losing forests at increasing rates of more than 1% annually, the Forest Resources Assessment did not fail to note that some countries made gains in forest area that summed up to 5.1 million ha annually. Bryant *et al*. (1997) analyzed the state of the world's frontier forests[1] and reported that 39% of the earth's frontier forest is threatened by logging, agricultural clearing and other human activity. While stating that half of today's frontier forest lies in the inhospitable boreal regions within Canada, Russia and Alaska, this study asserted that as much as 75% of this forest worldwide was threatened.

Assessment of the rate and extent of deforestation suffers from serious lack of data, poor quality data when it exists, and inconsistencies in available data even from some

[1] The term "frontier forests" was coined in this 1997 study by the World Resources Institute to describe forest areas that are relatively undisturbed by human activity and are large enough to maintain their biodiversity including viable populations of different species.

"reliable sources". Problems associated with the quality and availability of global forest data can be traced to issues which range from subtle ones like the definition of what comprises forests[2] among researchers to profound ones like national efforts to portray an environmentally friendly image to the international community by states. There however seems to be a general consensus on the fact that global forests area has or is witnessing a decline.

Given the importance of forests and forestry resources to the social, economic and cultural development of the world today, a lot of research is being carried out and a lot of literature has emerged attempting to explain the causes of deforestation. Some general characteristics can be identified on most of the literature that seeks to explain deforestation. First, there is an over-emphasis on the role played by poverty and population in causing deforestation. Second, causes of deforestation are treated more or less in isolation—deforestation is not viewed as the outcome of a combination of factors. Few analyses make use of the wider context in explaining deforestation: a majority is concerned with what is observed on the ground and seem to draw inspiration from this in their analysis.

Some authors do make the difference between direct (proximate) causes of deforestation and indirect (underlying or other) causes.[3] Direct causes are taken to be factors like: agricultural expansion (shifting and permanent cultivation, cattle rearing), wood extraction (lumbering, fuel-wood extraction, charcoal production), as well as infrastructural expansion and development (the expansion of public socioeconomic infrastructure, settlement).[4] Indirect causes are taken to be macroeconomic factors, social and political factors at state and international level.

2 The Issue

From available literature one can group causes of deforestation into three classes based on the driving explanation behind each cause.

Utility sensitive causes attributed to deforestation assume that the action of cutting down trees constitute the cause for trees being cut down. All activities for which forest clearing is required are taken to be the causes of deforestation. These include activities such as forest clearing for agriculture, fuel wood harvesting, logging, and others (Allen and Barnes, 1985). Hence, the use for which land is employed (agriculture, habitation, ranching) or the process of resource extraction from the forest (fuel wood harvesting,

[2] Matthews *et al*. (2000, pp. 14) uses a table to show different threshold values used in the definition of between countries and prominent international bodies. Such differences make common analysis difficult at almost every level.

[3] Fearnside (1985), Scrieciu (2001), Hein van Gils *et al*. (2006) as well as Geist and Lambin (2001) identified the same set of proximate causes.

[4] Geist and Lambin (2001) added to these proximate causes, two sets of underlying causes: on the one hand economic factors and policy/institutional factors and on the other hand technological, cultural and demographic factors. These depended on still another set of factors: land characteristics, biophysical drivers and social trigger events.

logging) are the causes for which forest is cleared.[5] Such arguments do not explain why people make choices to use the land for one purpose (which involves clearing its vegetation) instead of another (which may leave its vegetation intact). In other words, why is a particular portion of forest cleared for farmland instead of leaving it for tourism, for its aesthetic value, or for the commercialization of the seeds it produces? The action of clearing the forest is the outcome of a judgment that favors clearing the land as opposed to leaving it. The cause of deforestation can therefore not be the action of clearing the land but rather the factors that lead this judgment to favor clearing the forest rather than using it for any other non-clearing related activity. Some authors have used individual case studies to show that the use for which the land is put is simply a perverse outcome of institutional inefficiencies (Fearnside, 1985; Hecht *et al*., 1988 on the Amazon; Brothers, 1997 on the Dominican Republic). Bryant *et al*. (1997) described activities for which land is put when it is cleared as symptoms of the disease (deforestation). Symptoms are very different from causes and this is an important point to note within the framework of this paper.

Income sensitive causes attribute deforestation to income stress—poverty. Consequently, drivers of poverty like population growth are taken to be drivers of deforestation. This line of thought seems to hold that poor people depend on and use more environmental resources than the rich. Deforestation is therefore one of the consequences of this over-dependence and use of resources by the poor (Roper and Roberts, 1999; Swinton and Quiroz, 2003; Laurance, 1999; WCED, 1987[6]). According to this line of thought, the elimination of poverty should solve the problem of deforestation.[7] This group of arguments fails to explain the existence of large areas of relatively healthy forest cover in areas where poor populations have lived for hundreds of years and in some cases still do occupy.[8] More recent studies are casting serious

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[5] One such study is in a World Bank working paper where Margulis (2003) identifies cattle ranching, timber extraction, agriculture, and road construction as causes of deforestation in the Amazon. The statement that ends his list of causes is what this paper seeks to address. "*There are numerous alternative sustainable activities that could substitute cattle ranching and generate more substantial social economic and environmental benefits"*. Why then do people choose to cut down the forest instead of engaging in other activities that could give them income? Banana and Gombya-Ssembajje (1998) identified clearing for agriculture, logging, firewood harvesting and charcoal production as proximate causes of deforestation in Uganda.

[6] The World Commission on Environment and Development was one of the first authoritative bodies to put forward this theory of poverty-driven environmental degradation. Over the years, different bodies in the United Nations organization and the World Bank have used this argument to guide policy in a wide range of domains.

[7] Some studies however came up with a contrary view. Kahuthu (2006, pp. 66) stated that forest cover does not hold an Environmental Kuznet's curve-type relationship with levels of income.

[8] Forests such as those in south eastern Cameroon have served as homes and habitats for the pygmies (fondly called "original Cameroonians" by virtue of the fact that they were the first in the land) for centuries. These people (like many other forest peoples in the world) have to a large extent been living very basic and poor lives in symbiosis with their forest habitat (Gbetnkom, 2005 pp. 558). The forest cover that forms their habitat has remained stable over several generations until recently. The period following the institution of the structural adjustment program in Cameroon saw an annual increase in rates of deforestation from 1,110,000 ha during 1980–1985 to 205,000 ha in 2000 (World Bank, 1995; FAO, 2001a). Deforestation within this period is attributed to the rapid increase in logging by western companies. Hence, the deforestation rate in these forests is among some of the highest in tropical Africa (but the standards of living of pygmies have barely changed from what it used to be). This deforestation is not being carried out by the indigenous population but by companies owned and run by much wealthier

doubts over the credibility of this theory (Agudelo *et al*., 2003; Ravenborg, 2003; Brothers, 1997). Ravenborg (2003) identifies two reasons for this. First, the concept that farmers look for short-term economic gains with little regard for long term sustainability has been proven false. Second, the cause-effect relationship between poverty and environmental degradation is based on anecdotal evidence.[9] Angelsen and Kaimowitz (1999) question this theory too. They argue among other things that if the clearing of forests demands investment, it is the rich who are better placed in affording this investment. Income sensitive arguments also attribute deforestation to population growth. They hold that increased population growth leads to increased demand for forest land and resources and hence deforestation. The high rates of deforestation in tropical rainforests are attributed to increased population growth which is one of the main drivers of poverty there. Zhang *et al*. (2000) found in a study using panel data from the Hainan Island in China that population growth is the cause of the loss of natural forest even though it is positively related to plantation forests. This study suggests that population growth would have a greater influence on deforestation in the earlier stages of economic development but as the economy grows and techniques in silviculture advance, some good locations and productive bare lands could be afforested. Other studies have come to the conclusion that higher population lead to a more careful management of forest resources because people perceive the scarcity of the resources and see the urgent need of protecting them (Ostrom, 1999; McKean, 1992; Wade, 1994). A typical example is the perception that used to be held about the infinity of forest resources of the Himalayas. As a result, these resources were care-freely chopped down and used as train fuel or its wood (like in the Amazon) simply burnt to give way to subsistence farmland. Moran (2005, pp. 19) points to evidence that in areas of low populations in forest areas, attention to the vulnerability of forest resources is not given sufficient scrutiny. The validity of the population thesis is being challenged and it is accused of being based on flawed data and incorrectly specified models (Angelsen and Kaimowitz 1999; Leach and Fairhead, 2000).[10] According to Leach and Fairhead (2000), "a number of influential analyses of forest cover change have explicitly used population growth as a proxy for vegetation change in the absence of other data" making neo-Malthusian assumptions on local population-forest cover relationships to be embedded in the forest statistics.

Institutionally sensitive causes hold that deforestation occurs when institutions are too weak to control it or create an enabling environment for it (Laurance, 1999). This group of causes sees the illegal harvesting of lumber, poor policies of forest conservation and all aspects of weak national and international governance as being root causes of deforestation. They describe the national and international framework within which

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peoples and communities. In the same light, Williams (1990, pp. 182) notes that the dense rich tropical forest that extended from Pernanbuco to Porto Allegre (approximately 780,000 square kilometers (sq.km.)) was healthy in the hands of indigenous Indians in pre-Columbian time. It only began suffering destruction after European "invasion".

[9] Ravenborg (2003) outlines his arguments in a study of poverty and environmental degradation in the Nicaraguan hillsides in which he finds that non-poor farmers rather than poor farmers are responsible for most of the environmental degradation. He stresses on the importance of making the difference between "poverty as a state of deprivation" and "poverty as a relational phenomenon" when such analysis are being made.

[10] Examples of such models given by Leach and Fairhead (2000, pp. 25), with cites from other authors include: IDIOM, developed by the Tropenbos Program and GEOMOD.

deforestation takes place. These factors no doubt determine the severity or rate at which deforestation may proceed or in certain cases may determine if it will exist at all. This line of thought also adequately explains the role of international institutions in shaping or in some cases even determining national policies which have a direct influence in deforestation. They however rarely duel on the role of local collective action vis-à-vis state or international action towards deforestation: the role played by local communities in resisting activities that lead to negative change in forest cover at local level.[11]

3 Goal

This study seeks to outline the causes of deforestation which minimize the weaknesses of the above three classes of causes. It seeks to identify drivers of deforestation whose cause-effect relationships could be justified within the context of systems analysis. In this purely theoretical framework, the arguments will be limited to a level of complexity that should explain the motivation for forest clearing at the level of the person or persons who take or direct the initiative of clearing forests.

The whole idea is to understand why a person or people will choose to make the choice of cutting down the forest to meet his needs when they could still have met these needs through other means. Notwithstanding the large amount of literature that already exist in this subject, little seems to explain controversies in the manifestation of certain variables like population and poverty which seem to be variables of choice in many cases for explaining deforestation. Tools for this analysis will be the Hyde model of forest land use change, and tools of systems analysis—causal loop diagramming.

This study makes two assumptions (with a plausible mimicry of reality) on its analysis of deforestation. The first is that *alternative paths of action are available to economic goals that are sought by people*. Examples are that poor people could choose to migrate to towns, live hunter gatherer lives, or rear small livestock instead of cutting trees for farmland. If they choose to cut down trees for farming, then farming is not the cause of cutting down the trees. Rather, they have put together a group of factors that eliminate all other alternative paths of making a life and have come to the conclusion that cutting trees for farmland is the better option. The reasons for which all other courses of action are eliminated and the choice of cutting down forests is made should be the causes of deforestation. This example can also be applied to a rich capitalist who chooses to invest his money. Why would he choose to invest in lumbering or real estate that may involve clearing trees instead of textiles or telecommunications?

The second is that *the process of land-use and associated deforestation is a complex one regulated by complicated sets of factors which are changing all the time to respond to new circumstances*. There is therefore no overly simplistic model that can explain this

[11] Several of such local-based actions have been witnessed in recent history where individuals or small communalities stifle national and international projects that would have led to deforestation. Among individuals, efforts of activists like Wangari Maathai of Kenya and Vandana Shiva of India are noteworthy. Exemplary communities include the diverse grassroots organizations that developed in the Indian sub-continent: ranging from the Chipko Movement in the Himalayan region of Uttar Pradesh to the Silent Valley Movement of the Ghats region in the Indian south west.

process in full with isolated variables. Nevertheless, it is accepted that single variables may significantly drive the process of deforestation but can by no means operate in isolation. Within this framework, it is necessary to make the difference between causative factors of deforestation and factors which may manifest a correlation-type relationship with deforestation. For example, the fact that there are high rates of deforestation where incomes are low does not necessarily mean that low incomes cause deforestation. It could mean that the same factor(s) which lead to low income lead to deforestation, or that low incomes stimulate a factor that causes deforestation, or even still that deforestation leads to low incomes.

The discussion will be directed particularly to the fate of forests in the zone of open access resources denoted by the area B to D in the graphical representation of the Hyde Model (Figure 1). This choice is made for a number of reasons: this zone is near enough for people to access compared to the zone beyond D; the exercise of property rights in this zone is hampered by high transaction costs and there is therefore no protection of resources in it. The zone therefore offers an opportunity for the study of dynamics in resource use that are not clouded by property rights and restrictions on accessibility. This zone however is in constant interaction with the two adjoining zones around it and an understanding of the full dynamics of resource use here cannot be made in total isolation. The situation of other zones will therefore be analyzed when they influence the zone of open access resources.

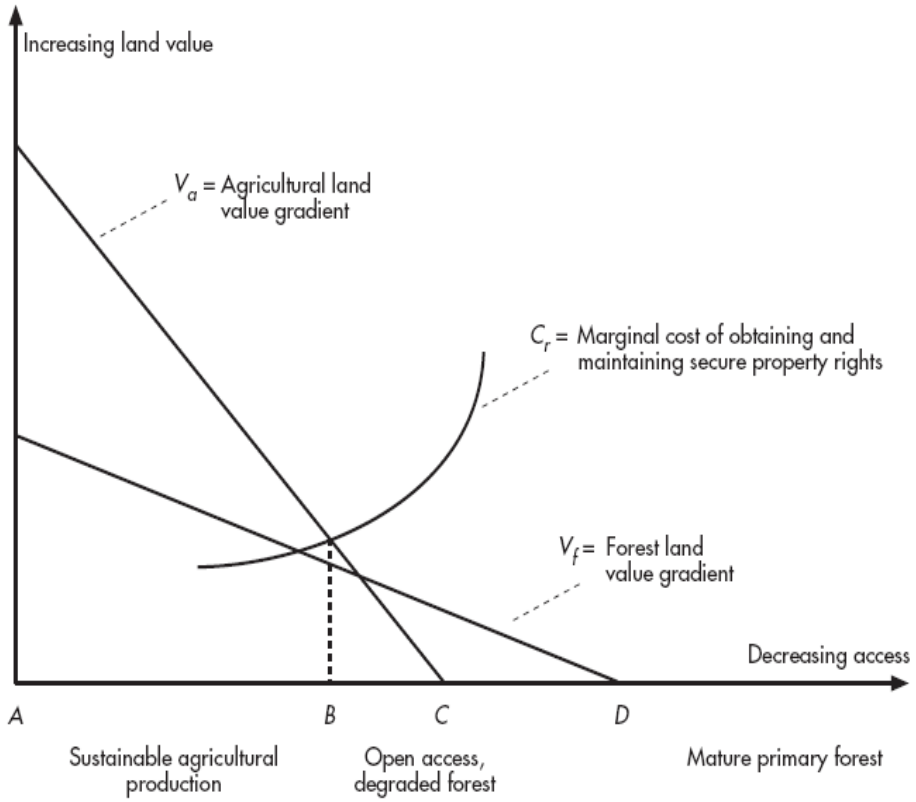


Figure 1: Graphical Representation of the Hyde Model. Source: Hyde (2005).

Some authors have attempted to understand the reasoning that goes on before people make choices that favor cutting down forests to meet their needs rather than meeting these needs through different means. Most of these analyses have economic underpinnings. This is largely understandable in cases where one considers forests as economic resources. Within the scope of this paper, such a consideration will be implicit though it is acknowledged that other considerations may alter economic undertones to varying degrees depending on a wide number of variables. One such model is that developed by William F. Hyde and it is going to guide the analysis in this paper.

4 The Hyde Model

The model developed by William F. Hyde draws from two models: the forest-transition model and Von Thunen's Theory of land use. The forest transition model is based on the observation that forests begin by undergoing a rapid rate of loss which reduces the availability of its resources and increases prices for them. The threat of this forest loss and the price increase that results discourages further depletion of forest resources and may even induce investments in them which enhance forest development (Mather *et al*., 1999). Von Thunen's theory of land use predicts a concentric circle of rings developing around a central point with decreasing land values as one moved away from this center. This was based on a number of assumptions.[12] Hyde's model (see Hyde, 2005; Hyde and Köhlin, 2000; Dangi and Hyde, 2001) is therefore a tool of analysis that integrates time and space in describing the evolution of forest land-use and resources. Not only does it inject a dynamic, progressive attribute to forest land-use change but it also gives the opportunity for each stage in this development to be frozen for a closer observation of details implicit in their dynamics. Figure 1 is a simplistic graphical representation of this model and shows the relationship between agricultural and forest land value, as well as the evolution of the marginal cost of obtaining and maintaining secure property rights in relation to distance from the center. When these functions are put together, one can identify zones where sustainable agriculture, open access forests and mature forests can be found.

The model is based on the following set of assumptions:[13]

(a) Settlement and its local market occur at the point A which is the center of economic activities.

(b) The value of agricultural land around this settlement depends on the net farm gate price of agricultural products. It is greatest when the farm gate is nearest the local market and transportation costs are lowest. This value declines with decreasing access to the market (or with increasing transportation costs which is related to the distance from the market center).

[12] Some of the main assumptions were that: the city is centrally located within a self-sufficient "Isolated State" which has no external influences; this Isolated State is surrounded unoccupied wilderness of uniform fertility, access and other economic advantages; and that the action of farmers is aimed at maximizing profits.

[13] These assumptions have been put together from all of Professor Hyde's works consulted for this paper especially from Hyde (2004, pp. 3).

(c) Agricultural production is purely an economic venture such that when the costs of production exceed returns, there will be no production. The land could be used for another activity which guarantees positive returns on investment of time, energy or resources.

(d) Agricultural land is managed by households (particularly land at the frontier). They absorb some transaction costs (which increase as the level of public infrastructure and effective control decline with distance from the center) in the process.

In the model, the forest frontier will evolve through three stages. In the first stage (the New Forest Frontier) the marginal value of agricultural land will decrease with distance from the center due to increased cost of manufactured goods used for agriculture and the cost of transportation. Besides these costs, there are also "transaction costs" which increase with distance from the market center.[14] This means net farm-gate value of agricultural products will fall as one moves away from the center. At a certain point (given as B in Figure 1) the cost of securely owning and maintaining a piece of land will just be equal to the net agricultural value of the land. Beyond this point, given that it is economically unprofitable investing in land for permanent agricultural purposes, people use the land here and its resources as open access with little or no protection (except in few cases where communities and/or governments may want to continue protecting them for largely non-economic reasons). The zone between B through C to D support open access activity which can reap some benefits with little or no investments of transaction costs. Beyond D the costs of open access activities are greater than the benefits and resources here are not exploited because they offer no economically sound basis for exploitation—that is the land has no economic value.

From Figure 1, the agricultural land value gradient (V_a) is high at the center but falls steeply with distance from it. The forest land value gradient (V_f) on the other hand is lower at the center but falls much slowly with distance. The marginal cost of obtaining and maintaining secure property rights (C_r) increases with distance from the center. AB therefore represents the zone where V_a is greater than C_r (the zone where agricultural production is profitable). Beyond B, agricultural productivity is not profitable because of the high value of C_r but open access activity is profitable because the inputs of C_r are not needed. Open access activity continues up to D where the net yield of the activity just equals the amount of effort and time employed in it. Beyond D, the value of open access activity is negative and so forests do grow to maturity.

In stage two of the model (the Developing Forest Frontier), agriculture is seen to be making use of some open access land as agricultural land values increase. The value of C is pushed towards D and correspondingly D is pushed into the periphery. The importance of cost to product extraction and hence forest evolution is seen along the D boundary where high-valued timber products are harvested and low-valued ones left standing. While distance from the center was the overriding factor determining the rate of forest evolution in the first stage, at the second stage the opportunity cost of labor and

[14] Hyde defines transaction costs as the cost of securing, exercising and maintaining property rights on a piece of landed property and resources. This cost increases with distance from the center until it becomes economically unprofitable incurring them. See Hyde (2004, pp. 3) for a discussion of the difference between agricultural management costs and transaction costs.

capital in extracting forest resources also comes into focus. This is because at greater distances, more labor and capital has to be employed in getting forest resources to the market.

Stage three of the model (Mature Forest Frontier) occurs when the forest frontier has become so far from the center that the harvesting of forest products from them offer no economic benefit. This stimulates the search for or development of substitutes which leads to limits in the extraction and use of forest products. Hyde argues that the substitution could be in terms of the consumption of forests products or in their production.

From the model in Figure 1, it can be seen that the forest land and resources that are rendered open access beyond the point B could suffer from over exploitation and degradation. Deforestation that occurs at this point can be blamed on a number of factors with the status of forest tenureship playing a primordial role. Figure 2 represents a basic causal loop diagram[15] of the nature of relationships that exist between main variables of the Hyde Model. The reinforcing loop R created between land value and the open access status of forests is the main driver of deforestation in open access forests. The role of distance in causing deforestation has to pass through property rights and its influence on land value. However, both determine the state of forest tenureship which is vital in determining the occurrence or not of deforestation.

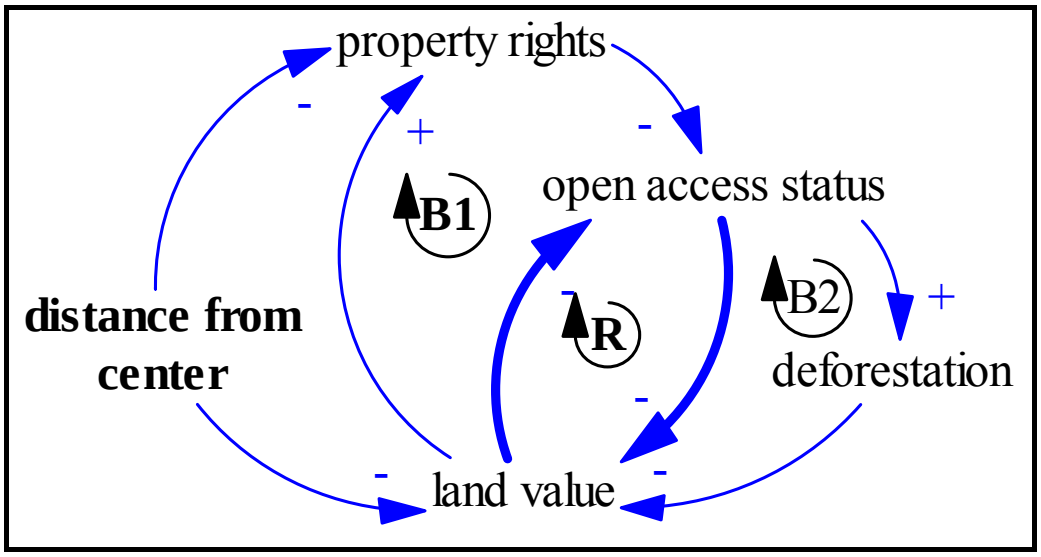


Figure 2: Causal Loop Diagram Showing Relationship of Main Variables in the Hyde Model. Source: Author's construction.

[15] A reinforcing loop is one in which the interactions are such that each action adds to the other. Where an action produces a result which promotes more of the same action is representative of a reinforcing loop. It is represented in this and subsequent causal loop diagrams with **R**. This kind of loop generates an exponential growth or fall. Balancing processes generate the forces or situations of resistance, which eventually limit growth. It is represented in this and subsequent causal loop diagrams with **B**. This kind of loop generates an linear growth or fall.

Other authors have sought to characterize land-use into three transitional categories similar to the Hyde Model. Foley *et al*. (2005) in their review of *Global Consequences of Land Use* identified broadly three "Land-use Transitions". There is the pre-settlement natural vegetation stage of land-use. This stage begins being modified when humans settle on the land. The second is the subsistence agriculture and small-scale farms stage when settled populations significantly modify the land (with little or no drive to intensification). The last is that of agricultural intensification, urbanization and the protection of recreational lands. These stages largely correspond to the first, second and third stages of the Hyde model and though Hyde is more particular about forests and the evolution of its frontiers, the notion of land-use change that runs through all models is strongly unifying. Much can be drawn from the assertion made by Foley *et al*. (2005) that *"Different parts of the world are in different transition stages…"* and that different societies do not move linearly through these stages: while some move easily through different stages, others stagnate in one stage or the other.[16] This brings the question of whether land-use changes (and by implication forest cover changes) are driven by factors which drive changes within different stages of the evolution of human occupation of the land.

5 Open Access Property

5.1 The Concept and Implications for Forest Resource Use

The term open access resource has become increasingly common in literature, discussions and debates on property regimes of natural resources. There is however significant confusion in the use of the term. It is necessary to make the difference between this term and others like common pool resources and public goods which have been used in certain cases as synonyms. Mckean (2000) defines *common pool resources* as those *"…that can be kept from potential users only at great cost or with difficulty but that are subtractable in consumption and can thus disappear"*. Tucker and Ostrom (2005) listed forests, watersheds, oceans, fisheries and the stratosphere as examples of common pool resources with these characteristics and added that even though they are important for humanity, their integrity could be threatened if they are overused. Mckean (2000) made the difference between goods or (property) which are things with *"…inherent physical characteristic(s)…"* and property regimes which are man-made constructs on accessing goods and services. She defined common property regime as a system of property rights in which a group of users share the rights and responsibilities towards a resource. To the above definition of common property resources, Heltberg (2002) added a condition of access to these resources*:"…access rules are defined with respect to community membership"*. He further explains that property rights could be vested in a body in the community like a tribe, village, user committees, cooperatives, local governments, etc.[17] *Public goods* on the other hand are goods that can be consumed by many people at the same time and whose consumption by one person(s)

[16] They attribute this to the fact that different parts of the world have different histories, economic and social conditions as well as ecological contexts.

[17] Heltberg (2002) defines, characterizes and makes differences between different property regimes. He also uses game theory to model collective action within the context of a dynamic natural resource base.

does not deprive its use by another. Users of public goods must not be able to exclude others from the consumption of the same good. Few goods can satisfy such an evasive definition. In many cases water, major roads, canals, bridges and the like are described wrongly as public goods. They do not satisfy the twin conditions of: having the potential of being consumed by many at the same time wherein the consumption by one person does not affect that of another, and one person not being able to exclude the other from its consumption. Radio broadcast and state military defense are examples of manmade goods that may to a large degree satisfy these twin conditions while sunlight ozone and air are examples of ecological public goods which satisfy the two conditions. The above definition of public goods differs from that of *state property resources* which Heltberg (2002) defines as resources formally under state ownership and control. The state can define rules of access and conservation. He further argues that state-owned resources are likely to degenerate into open access if their illegal exploitation by non-state parties goes unchecked—the tropical forests are an example.

The nature of certain resources makes them open for consumption by many at a time but their consumption by one user affects the ability of another user to consume the same resource. These are *open access resources* where there are no private property rights or common property regime which regulates access to and exploitation of this resource. In other words, these are resources over which nobody or group of persons or institution has or exercises any ownership and/or control.

Two conditions induce people to exercise rights over resources:

- The resource must be important enough to justify the cost of exercising rights over it. Since the exercising of rights entail costs in various forms, only valuable resources can attract the exercise of rights over them.
- There must be perceived scarcity of the resource. It must be noted that perceived scarcity may not be scarcity for real. As long as people know or even think wrongly that a resource is scarce, they will seek to exercise some form of rights (private or common) over it.

The two conditions above do not operate in isolation. Rather, they work together to determine whether rights will be exercised over a resource or not. When these two conditions are not met, there is little likelihood that people will worry to protect its exploitation and the resource can become open access. The collapse of the Atlantic cod stock is one glaring example that can be used to illustrate the fate of open access resources which happen to have some market value. Besides harvesting cod on a large-scale off the Massachusetts Bay to trade in Boston where it eventually ended in the Caribbean as slave food, cod became one of the major trading commodities in the transatlantic triangular trade in the 17th and 18th centuries. According to the Boston History and Innovation Collaborative (2006), the Boston Light and Long Wharf was an initiative built largely on cod trade and was used to prop up the global trade in cod. Cod fishing expanded to Canada's Newfoundland where several communities developed a cod-based economy. There was over fishing on Newfoundland's inshore and Canada's deep sea with little regulation to regulate harvesting levels or practice of the activity. As fishing technology improved, more efficient vessels and methods enabled even more intense harvesting of cod as foreign vessels competed with each other on international waters for harvesting the fish. On land, the demand for cod was continuously being

fueled by international trade and growing access to markets. So great was the pressure on cod that stocks (once thought to be mythically inexhaustible) declined by about 95% of its volume from 1990 to 1994 (Berril quoted by the Boston History and Innovation Collaborative, 2006).

Given that no rights are exercised over open access resources, there is no control over the number of resources that are exploited from them. People compete with each other in extracting resources from these pools. This competition is fueled by the thought that: *"if I do not take out this resource for my benefit, another person will take it out for his*" and "*I must take out as much as I can before it is completely taken out by others".* Such logic is partly driven by uncertainty and it in turn drives the degradation of open access resources irrespective of whether these resources are found within the vicinity of rich or poor residents and notwithstanding the size of the population. Population size could come in to determine how fast or slow the degradation could evolve but it is definitely not the cause of the degradation. The cause is the fact that the property has no secure rights being exercised over it and people are competing in selfish desires of making the most of it while it lasts. Such competition for resource extraction owing to the absence of meaningful rights over them could lead to large quantities of forest resources being depleted over relatively short periods of time. This partly explains why cases of rapid rates of deforestation exist that do not correlate with population densities.

From the above analogy, it follows that open access forests are more liable to deforestation than forests over which people have and exercise secure property rights. Secure property rights equally mean rights to use the forest resources the way one chooses. However, the pressure of *competitive harvesting*[18] that characterizes open access resources does not manifest in forests with ownership and rights.

6 Drivers of Deforestation

Being the complex process it is, deforestation cannot be pinned down to any particular cause. Even in the most simplistic analysis of a single case, numerous factors will be held accountable. These factors relate in different complex relationships which differ from place to place, from time to time, and from one case of deforestation to the other. Any attempt at identifying particular drivers of deforestation (such as is done below) is therefore an effort to significantly simplify reality so as to be able to make sense of it. As would be observed, most if not all drivers of deforestation do relate and interrelate with each other—at different levels and in different places with a resulting variation in the character of deforestation. Like current literature, this paper identifies certain causes as being direct. These direct causes are however driven by only one indirect (underlying cause).

[18] This can be taken to mean the extraction of resources beyond levels that the harvester would have harvested if he/she exercised full and secure rights over these resources. This is characterized by the absence of an effort to develop this resource, the use of unsustainable harvesting tools and methods, exploitation of resources without a meaningful market drive or commensurate domestic demand, general wastefulness and selling of such resources at "give away" prices.

6.1 Underlying Cause of Deforestation

6.1.1 Demand for Forest Land and Resources

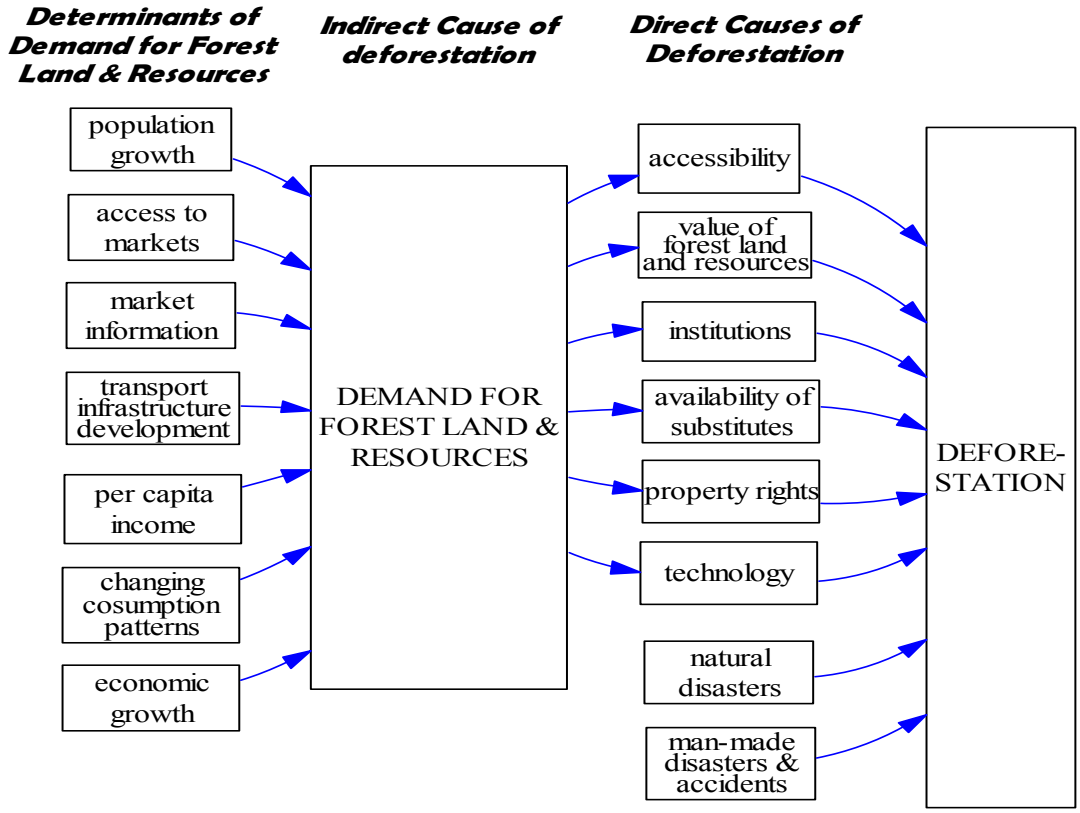
All cases of deliberate deforestation are associated with an attempt to put the forest land or resources to some use. Demand for forest land or resources is driven by a large number of factors (many of which may not be immediately apparent) during the process of deforestation. Irrespective of what these factors may be, the bottom line is that they drive a demand for forest land or resources which forms the underlying reason why people deforest. As seen in Figure 3, demand for forest land and/or resources could be driven by population growth, access to markets, economic growth, etc.

This demand does not however lead directly to deforestation. For this demand to translate to deforestation, it must depend on another group of factors (the direct causes). As seen in Figure 3 these are factors like accessibility, value of forest land and resources, institutions and others. In Figure 3(a), an illustrative example can be taken where the demand for forest resources is created by population growth or access to the market. For there to be deforestation, these resources must be accessible, the value of their exploitation must surpass the value of conserving these resources, there must be an absence of institutional barriers, and the exploitation of these resources must offer advantages over others which may be substitutes, and so on. Hence, the existence of demand for forest land and resources does not necessarily mean deforestation. For deforestation to occur or not occur, all direct causes play different roles at different levels (giving deforestation the complex character that will be discussed later).

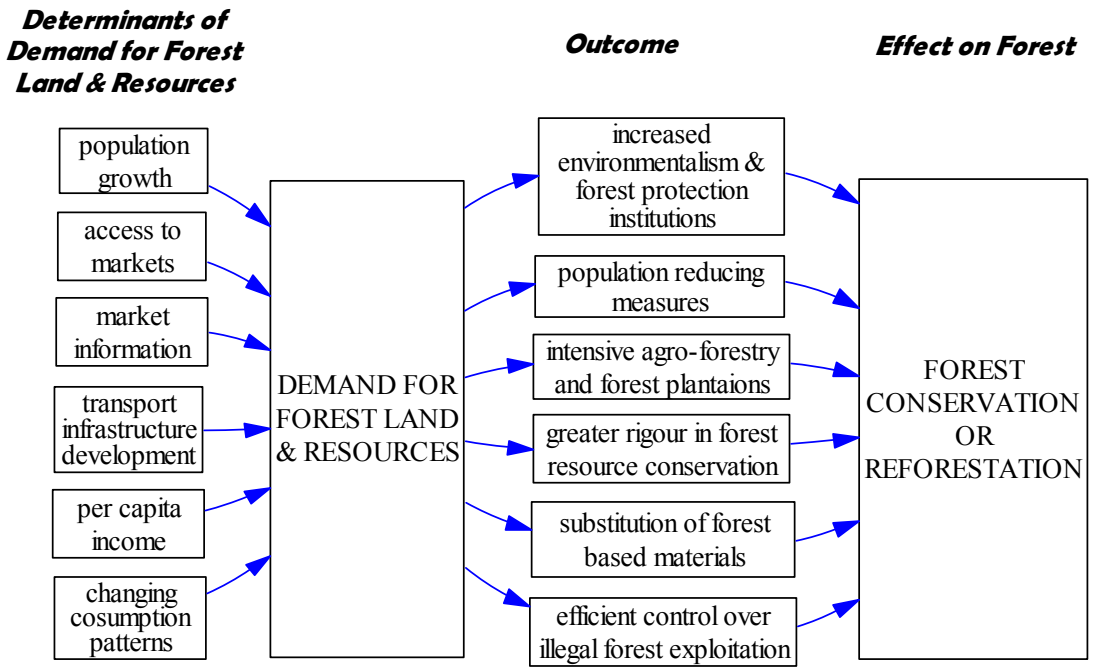
Demand for forest land and resources may lead to forest conservation or reforestation. Figure 3(b) shows that demand may lead to population reducing measures so as to be able to cope with the available resources, could lead to intensive agro-forestry and the development of more forest plantations to supply the market created by this demand, lead to greater rigor in forest conservation, etc. The fact that demand for forest land and resources could actually lead to reforestation or forest conservation rather than deforestation gives reason not to consider it as a direct cause (and even less so the factors which influence this demand).

In Figure 3(a) we find that not all direct causes of deforestation have demand for forest land and resources as the underlying cause. Natural and man-made disasters/accidents cannot be attributed to the demand for forest resources.[19] Man-made disasters like wars could be the outcome of a large number of factors which cannot be fairly boxed into a single category in this model. The same is true for natural disasters. Some man-made activities like mining and dam construction could lead to deforestation even when the goal is not the exploitation of forest resources. Such human activities fall under the category of man-made disasters and accidents.

[19] These factors are discussed in greater detail under direct causes of deforestation. Man-made disasters include wars, human activities like mining, accidental fires, etc. Natural disasters include volcanic eruptions, land slides, forest fires and others.



(a) When Demand for Forest Land and/or Resources Leads to Deforestation.



(b) When Demand for Forest Land and/or Resources Does Not Lead to Deforestation.

Figure 3: Direct and Indirect Causes of Deforestation. Source: Author's Construction.

6.2 Direct Causes

6.2.1 Value of Alternative Use of Forest Land

Economic rent describes the difference between the income that can be realized in the current use of a factor of production and the income that would be realized in the next most profitable use that the same factor of production could be put to. The assumption is implicit in economics that everyone is a profit and utility maximizer and so everyone would put his factors of production only in the most profitable area of production.

One can explain the evolution of three forest frontiers as identified by the Hyde model within the context of the relative benefits derived from using forest land for one economic purpose or the other. When an area of forest is newly settled, certain factors come in to determine whether the forest is going to undergo change and the rate at which this change is going to evolve if any.

6.2.1.1 Fate of Forest in the New Forest Frontier

The emergence of a new forest frontier is rarely the work of hunter-gatherers who originally inhabited the land. This frontier is in most cases created by displaced farmers coming into the land to make use of opportunities of open and cheaper land (Myers, 1996). Land development in a new frontier could either be planned and encouraged by a central authority (Moran, 1981) for purposes of "developing" the area or reducing pressure on land in other areas or unplanned. What ever the case, the outcome is a center of economic and socio-political power (representing point A in Hyde's Model) and a periphery around it in which land value decreases while transport and transaction costs increase with distance away from it.

6.2.1.2 The Developing Forest Frontier

Further transformation of the new forest frontier can depend on or be influenced by a number of factors like the existence of markets for products that can be obtained from the forest or forest land, access to the markets, information on the market, and so on.[20] These create the demand that justifies the effort of deforestation. These markets may be internal markets (within the community) or external markets (outside the community including the national and international sphere). It must be noted that the existence of markets only increases a demand for land which already existed in the community: created by the sedentary activities of the settlers and intended to meet own or home consumption.[21]

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[20] Hyde (2005) noted that some forms of marketing goes on even in very primitive societies. It must be noted too that in modern times markets are not limited by the geographical boundaries of a community especially if communication infrastructures and the socio-political will are favorable. This implies that the transformation of forest frontiers could be influenced by market opportunities that have nothing to do with the situation of the immediate environment.

[21] See Figure 8.

The size and dynamism of the market dictates what the demand for land to provide resources for this market is going to be. Big, rapidly expanding, promising markets will exert a greater demand for land to meet the supply of resources to it and so mean a greater rate of deforestation (if all other factors remain constant) and vice versa. Many examples can be cited of large areas of forests in the world that have been cleared to respond to demand for forest products for a wide variety of purposes which offered better economic income than leaving the forests standing.[22] While there is evidence to show that there was deforestation in many parts of South America before the arrival of Europeans, several cases of deforestation in this continent could be linked to the need to provide resources to European markets which in every respect was geographically remote to this area. The Levant region (present day Lebanon) witnessed a high rate of deforestation in the seventh century BC when Levantine iron was being exported to Babylon. As a consequence large areas of forest were cleared to provide fuel for the smelting plants (Goldewijk and Ramankutty, 2004).

From the discussion above, it can be seen that the reason why forest land or area cleared is because it is demanded by other activities whose returns are of a higher value than returns from keeping the forest. For this demand to translate into deforestation, it has to pass through the filter of: political and institutional will, accessibility, community resistance, value of the forest for alternative uses, forest tenure system, and availability of substitutes. In building basic assumptions for a land-use/cover diagram, Rayner *et al*. (1994) states as first assumption that "land-use is the outcome of competition among potential uses". Irrespective of whether the decision to put this land to one use or the other is taken at "micro-level" (such as a household) or "macro-level" (regional decision), land in one use is in conflict with other uses that could have been employed for it.[23]

It is essential to note that in a cause-effect relationship, there is a direct link between the above factors and deforestation.[24] When somebody wants to cut down a forest to plant food crops, cash crops, graze animals, log lumber, or undertake any other economic activity (because forest clearance is mainly for economic activities) he/she does not care to know what the population of his community or country is. What interests him is whether the products he will acquire from the use of the deforested area will yield a

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[22] The evolution of land-use in the east of the USA is a case in point. After the Civil War, displacement towards the west was stimulated by the agricultural opportunities that it offered compared to the east. As a consequence, large portions of forests in the west were cleared to make way for corn, wheat, soybeans and farm fencing. Because western soils offered better opportunities for farming, agriculture drifted westward while the abandonment of croplands stimulated the regrowth of forests in the eastern portions of the USA beginning in New England, then the Mid-Atlantic States and then the Southeast (Goldewijk and Ramankutty, 2004). The east had suffered its own era of land colonization and deforestation when the colonists just landed in the continent. By virtue of its abundance, it offered good economic value at the time it was being colonized but it lost its economic competitiveness to the west as it came to be understood that western soils were more fertile and could serve better in meeting the demand for agricultural produce in the expanding European market. The role of economic incentive is therefore important in determining land use.

[23] The terms "micro decision level", "macro decision level" and "global decision level" are used by Rayner *et al*. (1994) to describe scales of decision making in land-use. They put human decision making at the center of most manifestations of land-use/cover change.

[24] See Figure 9.

higher economic value for him than can be got by leaving the forest intact.[25] If the population and economic situation of the country or community does not offer a market, access to outside markets may still adequately induce deforestation. Goldewijk and Ramankutty (2004) have shown different examples across all continents of deforestation that occurred to respond to demand for forest products in markets that are geographically remote from the site of forest loss.[26]

One of the factors that can cause changes of land cover at this stage (or the evolution of the forest frontier) is the development of transport. This usually has the effect of increasing the geographical mobility of forest products through reduction of its cost. As the total cost of transportation of forest products fall, their profitability increases and people can exploit them over long distances and still make profits and so they push the margin of the common access region further into the zone of mature forests (see Figure 1). Cases where the development of local transportation stimulates demand for local goods as the local community gains access to city markets are many. Byrant *et al*. (1997) holds that this constitutes one of the greatest threats to existing forest cover. Transport facilities that offer opportunities for external trade can also have a tremendous effect on the demand for land to produce goods that can be supplied in external markets (see the discussion on accessibility).

6.2.1.3 Mature Forest Frontier

As the forest frontier develops, the economic activity at D recedes from the center A. As long as the delivered costs still fall below market prices, the activity can continue expanding. Sufficient expansion will move D so far from the center that the delivered costs and local prices can become so large that it will make economic sense to look for and use substitutes for forest products (Hyde, 2005).

Figure 4 shows the effect of a positive shift in the forest land value gradient (V_r). This could be caused by an appreciation in the value of forest products, development of road infrastructure which reduces net transport cost of forest products, or technological change. As C_r moves from D to D′ the area under open access pushes into the mature primary forest zone. In other words, the area that is open for deforestation is increased. Even though the area under sustainable forests increases by B to B″ it does not compensate for the increase in the area under open access.

Hyde makes the difference between consumption-oriented substitutes (where people may seek to look for alternatives to forest goods they use) and production related substitutes (where people seek to substitute unsustainable or less productive means of

[25] If he goes through the details of projecting the population trends to make his decision to deforest, it is not because a growing population should be a rationale for deforestation. Rather, it will be to help him know if such a population could be of demand value large enough to justify an economic investment of his labor and capital in deforesting the land.

[26] They summarize a history of land-use change over the last 300 years in all continents and show how demand for forest products for various forms of industrial development, and other forms of human activities led to deforestation within and beyond national borders. The argument here is that the population of an area does not need to be large for them to deforest. If there is a market for the forest products, information about this market and access to it, the resources will be deforested and marketed if the process yields an economic profit and the resources are accessible.

forestry with a more sustainable and productive one). Turner II *et al*. (1994) holds that forests at an advanced stage of development will experience increase due to the reversion of marginal land to forests and the concentration of agricultural production to more favorable areas.

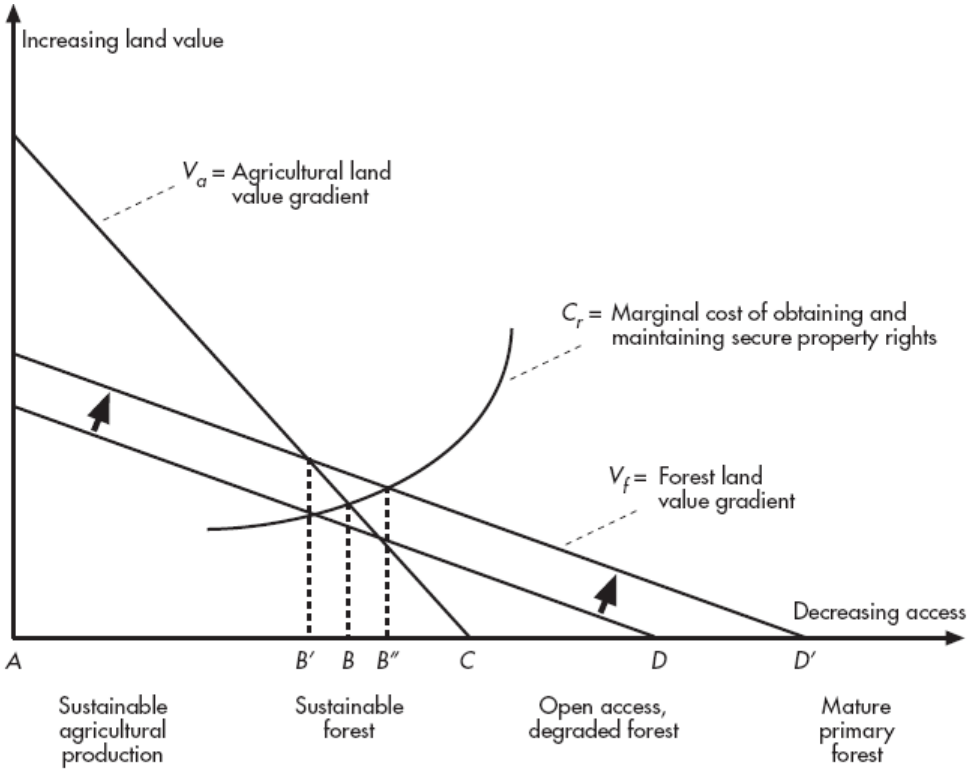

Figure 4: A Mature Forest Frontier in Hyde's Model. Source: Hyde (2005).

6.2.2 Forest Ownership or Property Rights[27]

As already seen above, no one invests in the protection of open access resources because no one owns them. In fact, the fate of open access resources has been explored by many authors since Garrett Hardin's *Tragedy of the Commons* (1968).[28] It must be noted here that ownership per se will not solve the problem of deforestation between point B and C. What matters is the security of rights that people or communities have over forest resources. As resources become more and more remote from the center of power that assures and enforces people's rights over them, so does the assertion of these rights diminish. The concept of transaction costs defined by Hyde in his model is

[27] Property rights here are not viewed within the context of who owns what. This is because forest resources under all tenure systems are liable to degradation irrespective of who in principle owns them. Property rights here are more concerned with how well the rights of individuals, communities or state can be asserted on the forests they own.

[28] Some authors have criticized Hardin for being confused between common property resources and open access resources (Ciriacy-Wantrup and Bishop, 1975). His illustrations were pointing to the tragedy of open access but erroneously termed tragedy of the commons.

essential because it determines what has to be given to effectively own and exercise rights over land as distance increases from the center.[29]

The area B to C exists in all forests which are sufficiently large to produce a point where the cost of secure property rights goes above the agricultural value of land falls below zero with distance from the market center irrespective of whether these forests exist in developing or developed countries or whether the central authority exercises control over unoccupied land or not. In other words, the type of contract under which land is occupied and used or preserved does not matter. They are all subject to deforestation when the right conditions are united. What matters is the security of tenureship.

The fact that people have the choice of preserving their forest resources when they have secure rights over them is in itself an indication that the probability of not deforesting under the pressure of competitive extraction is greater. With secure rights, people will conserve forests if the discounted benefits of conservation are greater than the benefits of using the resources today. On the other hand they will clear the forest and put it to more profitable use if the nominal value of conserved forests is low. Value of conserved forests is a term which may be very fluid in definition. It goes beyond economic value and may encompass issues of ethics and pleasure. In discussing crisis of the medieval economy, Cameron (1993, pp. 74) explains how landlords in the northern parts of Europe opposed deforestation to safeguard their hunting privileges. This was only possible because the landlords had fairly secure powers over these resources (enforced by often cruel draconian measures or acquired by societal status).[30]

In Figure 5, we can see that when there are no property rights exercised over a resource, people are never sure of the future of this resource. In the spirit of competitive consumption, they over-exploit it without investing or reinvesting in its sustainability. Even though Mendelsohn (1994) holds that the "tragedy of the commons" results in people under-investing in capital or land held jointly, it is difficult to contend that holding the land jointly alone should lead to under-investment. In the case of common property rights[31] if people are certain that the rules and regulations governing forest conservation and management is strong and functional in their community, they can invest in the development of common forestry resources. Studies by Dangi and Hyde (2001) in Nepal seem to confirm this to a large extent. Uncertainty can be caused by lack of participation on the management of a resource (which leave the participants with no knowledge of what may become of the resource) or insecure property rights over it. The reinforcing loop (R) in Figure 5 illustrates this condition. The balancing loop (B) suggests that when people invest less in a resource, they participate less in developing and managing it and this further fuels uncertainty which could drive comparative

[29] Banana and Gombya-Ssembajje (1998) argued that *"…if rules regulating access and use of forest resources (and by implication ownership of them) are not adequately enforced, the de facto condition becomes one of open access rather than secure tenure*".

[30] Matthews *et al*. (2000) explains how hunting in medieval Europe was held in such high esteem that large tracts of protected forests had to be preserved for the hunting privileges of the nobles. Infringement into them was punishable by death.

[31] Increasing literature is emerging to support the fact that the term "Tragedy of the Commons" used by Hardin (1968) was mistaken. Accounts in his article point to a case of rather "tragedy of open access" (see ibid 27).

extraction and further reduce investment in the resources. Dangi and Hyde (2001) demonstrated how increased participation of communities through community forest management initiatives in Nepal led to an increase in forest area from less than 10,000 ha in 1992 to over 651,000 ha in 1999. To a large extent, the quality of forests also increased as different communities invested more in improving their quality.

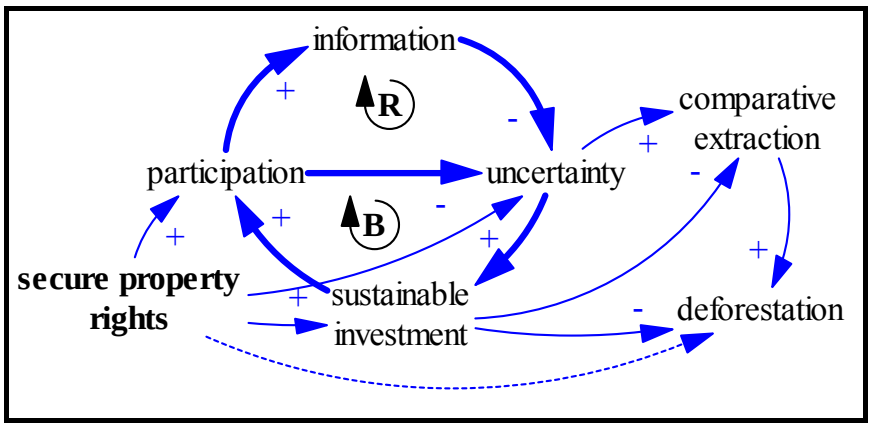

Figure 5: Secure Property Rights and Deforestation on Open Access Forest Resources. Note: The dotted line indicates that this relationship could either be positive or negative.[32] Source: Author's construction.

In summary, as long as people do not have or recognize the existence of secure and respected property rights over a forest resource or the entire production system, deforestation will occur notwithstanding the importance of the resource in question.

6.2.3 Forest Product Substitution

Though reliable physical and economic data regarding the distribution and rates of deforestation (especially in the tropics) is seriously lacking, there seems to be a consensus that the greatest rates of deforestation occur in tropical regions where poverty prevails (FAO, 2003, 2005; UN, 2002; WRI, 2000). Many authors have not spared to blame poverty for such deforestation though in many cases, the connection between poverty and deforestation is made on the basis of correlations rather than cause-effect relationships. Notwithstanding how clear or unclear the relationship between poverty and deforestation may be, the assumption underlying any of these arguments follows the logic that poor people depend more on forest resources (for which they have in most cases very few substitutes) than the rich. The argument goes that with their generally high rates of population growth, they over-exploit and destroy the forest. *Depending on resources* could be quite different from actually using these resources. Cavendish (2000) came to the conclusion that while poor households depended heavily on environmental resources, which could contribute up to 40% of their incomes in his study, richer households used greater quantities of environmental resources in total. It must be noted that even if poor households depended on environmental resources for

[32] Angelsen and Kaimowitz (1999) noted that land titles and more secure tenure could have contradictory effects. People could choose either to conserve the land or not and this decision may be controlled by a wide range of factors. Theories that model an automatic conservation of forest resources because they are under secure tenure systems are biased.

100% of their income, the total quantities used could still be much less than that of rich households.

There is nonetheless significant evidence to show that poor communities would depend less on environmental resources if they had access to affordable substitutes. In the Kilum-Ijim Mountain Forest communities of the North West in Cameroon, people were quick to adopt substitutes for materials, technologies and capacities when a 40,000 ha forest they depended heavily on came under conservation. Table 1 shows the different materials, technologies and capacities that were being used before the forest they depended on came under conservation and after it had been conserved.

Table 1: Materials, technologies and capacities that were substituted in the Kilum-Ijim communities as their main source (the forest) came under conservation. Source: Author's construction.

Domain of Substitution	Activity	Used Before Conservation	Used After Conservation
Materials	Wood carving	• mature forest tree species	• domestic substitutes (eucalyptus, cypress, fruit tees) • fast growing forest species grown on domestic agro-forestry plots
	Fuel wood	• mature, high charcoal-producing, slow-burning, smoke-efficient, forest tree species	• domestic substitutes (eucalyptus, cypress, fruit tees) • dead and fallen forest trees • saw dust on local, improved stoves
	Bee farming	• thatch for constructing traditional hives	• eucalyptus (a home-grown tree) for constructing Kenyan top-bar hives
	Construction	• thatch for rooftops	• corrugated metal sheets
Technologies and Capacity	Food crop farming	• shifting cultivation • long fallow cycles • low intensity agriculture • cultivation of few (staple) crops	• permanent farm plots • non-fallow farming • greater agricultural intensification (better fertilization, more rigorous seed selection, improved erosion control, etc.) • diversification of crop types with notable drive towards market gardening crops
	Agro-forestry	• inexistent	• individual and community agro-forestry practice • proliferation in the propagation of fast-growing wild and useful tree species
	Animal rearing	• largely extensive	• intensive rearing of some animal species • a greater variety of animals being reared

Poverty is therefore not the cause for deforestation when people over-depend on forestry resources for which they have no substitute. The reason why they will deforest and continue to do so even under severe restrictions is because they lack substitutes for forest products.[33] Dangi and Hyde (2000) illustrated that the hiring of guards and use of other methods to prevent poor farmers from harvesting fuel from an upper hillside that led to erosion in the lower farmlands owned by wealthy farmers was not successful in the village of Basantapur, Nepal. The rich farmers were not depending on the fuel wood harvested from these slopes because they could afford better substitutes for local fuel. Since these substitutes were not within the grasp of the poor, they had no choice to the fuel type they could use. In the absence of other forms of fuel, the rich would also have been using forest wood.

The simplified relationship in Figure 6 shows that in the absence of substitutes, people exploit and use forest products B1. As the availability of these resources declines, the quantities of resources used per quantity left increases because even at constant extraction, the total quantity available for use is low B2.

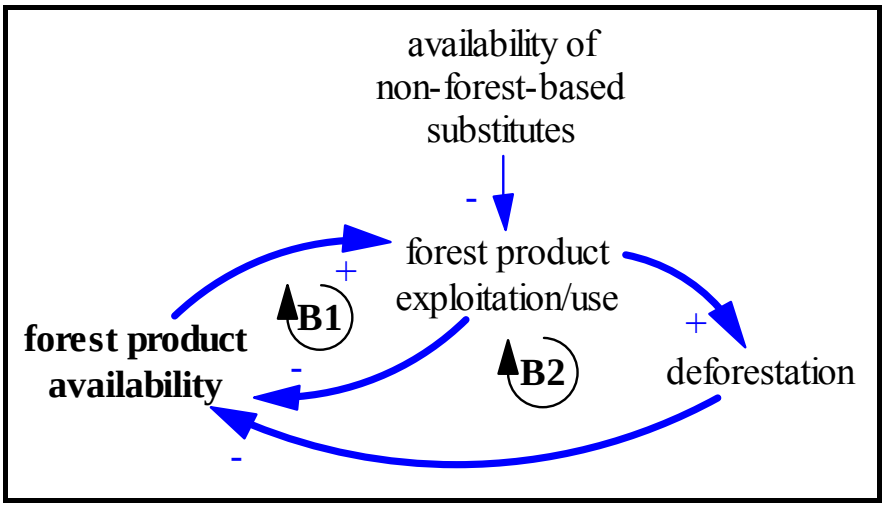

Figure 6: Deforestation Linked to Substitutes for Forest Products. Source: Author's construction.

6.2.4 Technology

The role technology plays in causing deforestation has received some of the least attention in research. Technology determines the extent to which certain causes of deforestation can be effective. It is important however to understand that technology may play both a positive and a negative role in influencing forest cover change. While greater technology may open more opportunities for deforestation in one case, it may

[33] People will choose to use "healthier" and "cleaner" alternatives to direct environmental resources if they have affordable substitutes. For example people will prefer using improved stoves for cooking and electricity for lighting that forest wood if such substitutes are affordable. In the same light, people will prefer doing white or blue-collar labor than clearing forests for subsistence cultivation in the tropics if they had the opportunity of getting these jobs.

actually permit a greater control over the phenomenon on the other hand. For example, increased agricultural land-use technology may put the economic value of land under forests less competitive to its use for agriculture and induce its being cleared. In another vein, this same technology may mean that less land under agriculture can be used to produce more yields than previously and farmland abandonment for other uses (possibly forest growth) may be the outcome. Growth in technology may equally increase the rate and level to which products and technologies are developed to replace the reliance on forest land and resources as seen in Figure 7.

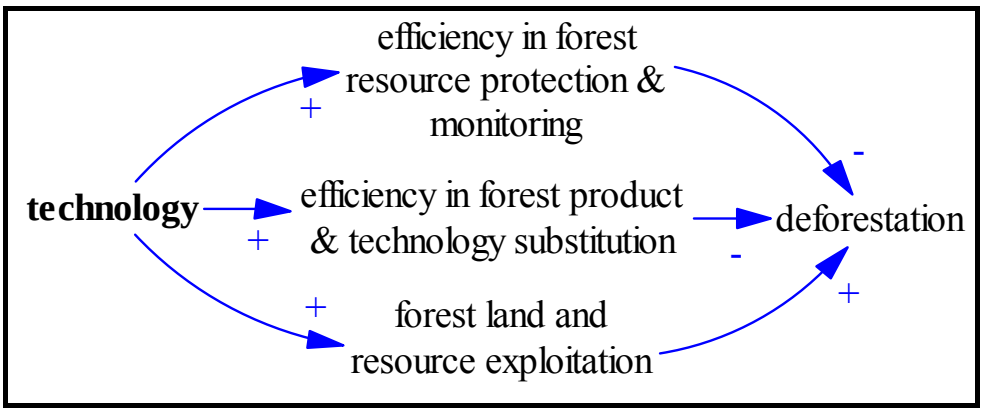

Figure 7: The Positive and Negative Roles Technology Can Play In Influencing Deforestation. Source: Author's Construction.

While there are many indirect roles that technology may play in determining the occurrence of deforestation, there are certain direct effects of technology that are worth mentioning: it can increase or decrease the accessibility to forest resources; determine the effectiveness with which governments, individuals and communities protect, monitor and manage forest resources; determine the degree to which substitutes for forest resources can be created; determine the value that will be attached to forest resources and hence the need to conserve or not to conserve them; facilitate the enforcement of tenure rights; and so on.

Technology is seen to play an important role in the evolution of the forest frontier in all stages of the Hyde Model. Hyde (2005) explains how improved forestry equipment can reduce the cost of removing the natural forest cover thereby shifting the net value function for timber to the right.

6.2.5 Institutions

Like technology, institutions play a very vital role in determining deforestation by influencing the existence and rates of manifestation of all other factors of causation. Institutions could range from anything as big as state or international bodies to small community groups managing their forest resources.[34] Small community-based

[34] Dangi and Hyde (2001) described the experiences of six community-based forest management institutions in Nepal and came up with deep insights on the dynamics that run through such bodies as they struggle to cope with issues of forest conservation and management.

institutions (like regional, national or international institutions) are capable of making decisions and carrying out activities which can greatly influence the evolution of forests cover in an area. Certain characteristics of institutions affect the way they can cause, manage or cope with changes in forest cover. These include economic viability, weakness or strength of these institutions, the system of governance and decision making that runs through them, and so on. These determine the kind of policies that institutions can undertake, the success or failure that is likely to accompany these policies and the effects that these policies are going to have on natural resources like forests.

Roper and Roberts (1999) identified certain policies that may seriously determine the evolution of forest cover in different societies. Many of them can be associated to the catastrophic rate of deforestation that has been going on in Brazil for several centuries now.

- Subsidized credit for the expansion of agriculture and livestock has, in many cases, been undertaken by governments in an attempt to attain different goals of economic growth and social well-being. Governments such as those of Brazil and Peru sponsored the colonization and "development" of large portions of the Amazon through these means. Forests are therefore cleared to give way to pasture land for beef cattle.
- A taxation system that favors the development of industries and regions that negatively impact on forest cover such as tax holidays for the importation of forest exploitation equipment. The government of Brazil created a duty-free zone in the city of Manaus which led to an exponential growth in urban and industrial activity and deforestation associated to demand for forest land and resources.
- Promoting a cash crop-based economy and extensive monoculture practices. The Brazilian Amazon has passed through different phases of practices of monoculture. Notable among these are the transitions from sugar cane to rubber, then coffee and now beef cattle. These are all extensive farming systems which demand large portions of land that is supplied mainly through deforesting the Amazon. This role is similar to that played by colonial authorities in early twentieth century Africa and Asia. In Nigeria for example the cultivation of tree crops like rubber, oil palm, cocoa and others for export was introduced and encouraged while timber exploitation concessions to British companies. All of these contributed to accelerate the loss of pristine rainforest cover.
- Substituting imports with local production of fuels and food crops that are not based on economic sense can lead to the conversion of forest land to meet this demand. This is usually undertaken to stimulate economic growth that attain self-sufficiency in these productions but the consequences to the environment are always enormous.
- Corrupt institutions can lead to quite dramatic rates of deforestation in different parts of the world. Corruption undermines the workability of almost every system in the resource management sector. In the case of forestry, it undermines every aspect of proper resource management: from facilitating the acquisition of illegal forest exploitation permits to endorsing unexecuted reforestation programs.

Institutions such as governments can play an important role in causing changes in forest cover. Hyde (2005) identified three main instruments of direct forest policy which could

be used to protect and conserve forest cover and resources: taxes in the form of income and property tax; incentives like financial assistance in afforestation programs, free seedlings, technical assistance; regulations like restrictions on harvests and shipments, reforestation policies, forest certification, etc. Brothers (1997) in his analysis of a village level view of deforestation in the Dominican Republic explained that governments could cause deforestation not only by promoting land colonization schemes and handing out subsidies to farmers but also through their relationship with the rural population.

6.2.6 Accessibility

Many researchers have attributed road infrastructure as one main cause of deforestation. It is argued that the construction of roads requires clearing vegetation that leads to deforestation (Geist and Lambin, 2001, pp. 87). The clearing that delimits the path or space occupied by a road is usually limited. This in itself does not constitute the bulk of the problem of deforestation.

The role roads play in increasing accessibility to forest resources seem to be a more complete explanation of the cause-effect relationship between road construction and deforestation. High-value forest products are bulky and cumbersome and need to be moved to the market at minimal cost. Good roads offer a fast and cheap means of moving these products to the market. It must be noted that accessibility does not only drive agents of deforestation like logging. It equally makes the use of fuel wood (another agent of deforestation) cheaper over long distances. Sights of trucks loaded with fuel wood destined for urban consumption are not unfamiliar sights in regions of tropical Africa and Asia. Matthews *et al*. (2000, pp. 22) argue that roads open up undisturbed mature forest areas to pioneer settlements, logging, and deforestation for different purposes. In the same light, the availability of roads makes hinterlands more accessible to different forms of land-uses that require clearing of vegetation such as agriculture and even habitation. Hyde (2005) explains that the improvement in access created by roads, make the land more valuable in all uses. These uses may then compete with the maintaining of forest cover over the land.

Figure 8 explains the influence of accessibility in the development of the forest frontier. The broken lines represent the former functions of agricultural and forest land value and the unbroken lines represent the new functions. The mature forest frontier for example moves from D to D1. Improved accessibility is seen to increase local agricultural and forest values, shifting functions for these values to the right. This shift therefore extends the area under permanent agriculture to the right as the zone of open access is pushed into the geographic interior (Hyde, 2005).

The expression "*where a road passes, development follows*" used in many parts of tropical Africa is synonymous to the opportunities of land resource colonization and exploitation that follows accessibility to them created by road construction. Goldewijk and Ramankutty (2004) identify large-scale infrastructural projects like the Trans-Amazonian Highway as being one of the root causes for the deforestation of the Amazon. It opens up large areas of pristine tropical forests for exploitation. People take advantage of the accessibility that comes with it to carve out new lands for settlement,

agriculture, cattle rearing and other forms of deforesting activities. According to Fearnside (1985) road building is one of the strongest forces behind deforestation because besides its direct effects, it drives positive feedback processes that reinforce the cycle of deforestation (note the two reinforcing loops in Figure 5).[35]

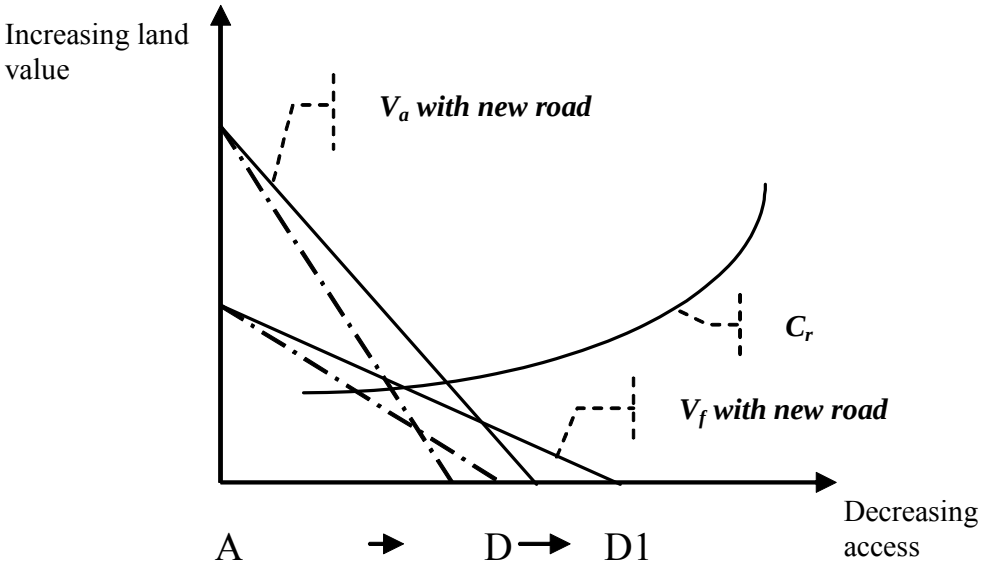

Figure 8: The Role of Accessibility in a Developing Forest Frontier. Source: Hyde (2005).

Accessibility may not necessarily be provided by roads alone. Deforestation has occurred in several areas of the world where waterways have been used to cheaply transport lumber to ports and harbors. In their review of land-use change, Goldewijk and Ramankutty (2004) explain that transport development of international magnitude such as the construction of the Suez Canal in 1869 and subsequently the Panama in 1914 significantly lowered transaction costs and boosted the amount of goods transported from Asia to Europe and from South America to North America, respectively. Large portions of the world which formerly did not have access to European markets could now benefit from trade which in most cases was in natural products.

The role accessibility to resources and markets play in driving deforestation had an even earlier history though its effects were most dramatic at the beginning of the seventeenth century. Williams (1990, pp. 180) noted the highlights of this transition during the period of European expansion from 1600–1850. When European trade ceased from pre-occupying itself with goods of small quantities and high value like perfumes, spices and fine cloth and engaged in the trade of bulky products for an increasingly richer population, forests had to be cleared to meet this new demand far beyond the geographical borders of Europe. With the development of sea and rail transport that

[35] Fearnside even argues that the development of roads is self reinforcing. This means that the more roads that are in an area the more there is a drive to construct many more. This is because as populations occupy the area because of its accessibility, there is need for the construction of roads to meet that infrastructural needs of these communities and hence more deforestation.

significantly reduced cost and transportation time, European markets could trade in tea from India and China, coffee from Brazil, sugar from the Caribbean, cotton from Asia and North America, and slaves from Africa (who provided the labor incentive for greater deforestation).

Applying this reasoning to the Hyde Model, one would say as transport infrastructure improves during the second stage of forest development, the net values of agricultural and forest land use increases. This has two main effects as noted by Hyde (2004)—extending agricultural activity in to the degraded open access region to the right of point B; pushing the extractive forestry activities to the right of D.

Figure 9 shows that increased transaction costs will, on the one hand, reduce the value of land and, on the other, reduce the exercise of property rights over the land and its resources (the reinforcing loop R1). These two factors determine whether the land becomes open access or not. Resources that become open-access reduce the tendency for people to exercise rights over them because they are over-exploited and their value relative to transaction costs further deteriorates (the reinforcing loops R1, R2 and R3). In another vein, if transaction costs fall because accessibility to this land has been increased, the land value will increase because high land values can support larger transaction costs. The dotted arrow denotes the role of choice that the forest property owners have in deciding what becomes of their forests. The role of economic incentives is important in deciding whether forests under secure property rights will be conserved or converted to other uses. Property rights play an important role in this system: serving as a pivot of two reinforcing loops. In Figure 9, it is seen that forest land and resource value as well as open access to forest resources depend on property rights (with which they form reinforcing loops R1 and R2). The loop R4 describes how deforestation can be reduced if an increase in forest land and resource value leads to an increase in property rights which in turn limits open access to these resources. These rights determine land value and determine the status of the forest (two critical factors which determine the overall dynamics of the system).

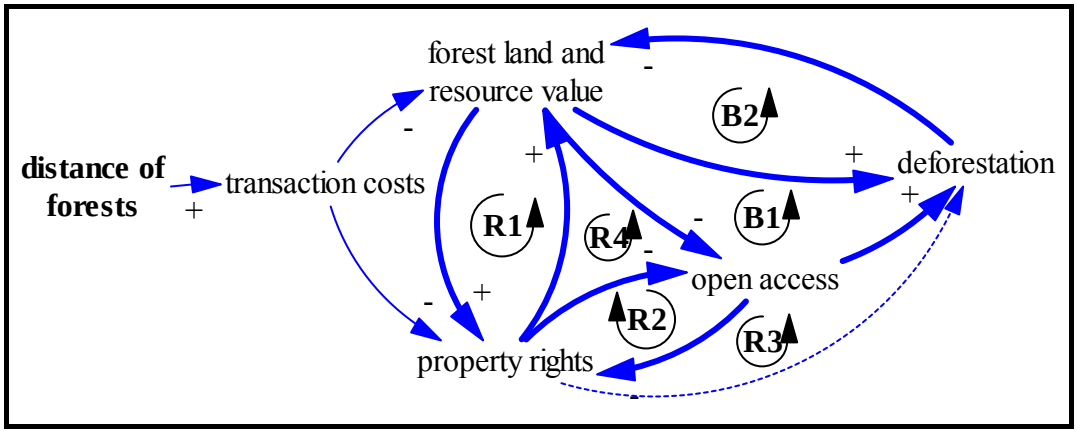

Figure 9: Influence of Accessibility (transaction costs) on Deforestation. Source: Author's construction. Note: The dotted line indicates that this relationship could either be positive or negative.

6.2.7 Natural Disasters

Deforestation originating from natural causes has been largely ignored in current literature. Pellegrini (unpublished) describe the division between natural and anthropogenic causes of deforestation as fictional arguing that many human sources of deforestation reduce the likelihood of natural disasters. While some cases of deforestation that could be termed natural actually have a human factor that aids or accelerates it (such as deforestation resulting from desertification on the southern fringes of the Sahara) others have basically nothing to do with human activities (such as that caused by volcanic eruptions). Besides volcanic eruptions, natural disasters such as hurricanes, landslides, climate change, predation by a variety of parasites and pests, forest fires could lead to significant amounts of deforestation. Within the context of this paper we can examine the role of forest fires only.

Gomes (2006) describes them as part of the dynamics of the planet earth. While it is argued that periodic flaming could be healthy for forests as they move through the path of evolution, the amount of forest that goes up in flames is increasingly becoming an issue of concern in many parts of the world. In Portugal for example where the forestry sector provides 3.2% of gross domestic product (GDP), 12% of industrial GDP, approximately 11% of exports and 260,000 jobs in direct and indirect employment (Gomes, 2006), forest fires could be a serious cause for concern. The situation is no different in many other countries of the temperate world as shown in Table 2.

Table 2: Number of Forest Fires and Burnt Area in Some Countries in Europe in the Last 25 Years. Source: European Forest Fire Information System (2005).

Number of fires	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
2004	21891	21394	2028(*)	6428	1748	53489
% of total in 2004	40.9	40.0	3.8	12.0	3.3	100
Average 1980-1989	6778	9514	4910	11571	1264	34036
Average 1990-1999	22250	18151	5537	11352	1748	59039
Average 2000-2004	26059	20779	4207	7696	1891	60633
Average 1980-2004	16823	15222	5020	10709	1583	49357
TOTAL (1980-2004)	420573	380551	125503	267718	39570	1233915

Burnt areas (ha)	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
2004	129652	134171	12500	60176	10267	346766
% of total in 2004	37.3	38.7	3.6	17.4	3.0	100
Average 1980-1989	74486	244788	39157	148485	52417	559331
Average 1990-1999	102203	161323	22695	108890	44108	439219
Average 2000-2004	189532	129106	32078	76764	36610	464090
Average 1980-2004	108582	188265	31156	118303	45932	492238
TOTAL (1980-2004)	2714547	4706633	778900	2957572	1148298	12305950

(*) number of fires for Southern France only

Forest fires being one of the ways nature drives evolution in forest ecosystems are not meant to be as severe and destructive as they have been in recent times. Their severity has been causes by the role of man in the ecosystem. As forest fires are regularly suppressed, large quantities of underbrush accumulate on the forest floor and serve as added fuel for the fires when they eventually do occur. It is expected that the incidences and frequency of forest fires will increase as global temperatures rise and this phenomenon could have disastrous circumstances on conserved forests in many parts of the world.

6.2.8 Man-made Disasters

Man-induced deforestation does not always result from the demand of forest land and resources. It could result from other forms of human activities that are not directed to the exploitation of these resources. Activities that create favorable conditions for landslides, accidental forest fires, accidental introduction of alien species into an ecosystem, and war are all examples of human activities that can lead to deforestation.

The uses of napalm and Agent Orange by the United States military during the Vietnam War and recently by the Indonesian military to fight rebel activity in East Timor are recent examples of the contribution of man-made accidents like wars to increased rates of deforestation in these two countries (Klubnikin and Causey, 2002). The driving factors of such activities are quite varied. This makes it difficult to frame them within a single category—hence they cannot be associated to a particular indirect cause.

7 The Holistic Nature of Deforestation

Deforestation is a product of multiple drivers. These drivers are different from one time to the other (which gives deforestation different characters as seen in different stages in the Hyde model) and from one place to the other (which makes it operate at different rates and intensities at different places). Irrespective of the time and place where it occurs, deforestation is an outcome of different causes, operating at different scales, at different times, and with different intensities.

The identification and analysis of individual drivers is done in order to understand the role they play as single factors in shaping the character of deforestation. It does not by any means undermine the fact that deforestation is the result of multiple factors operating together at different scales. Different aspects of the Hyde Model and associated cause-effect diagrams that explain them show how each driver of deforestation is more or less intimately linked to the other in the sub-systems. All of the diagrams (that explain cause-effect relationships of individual drivers of deforestation) could be merged into a big picture that defines the *deforestation system*. It is only with this approach and within this system that the complexity of the phenomenon of deforestation can be appreciated (see Figure 10).

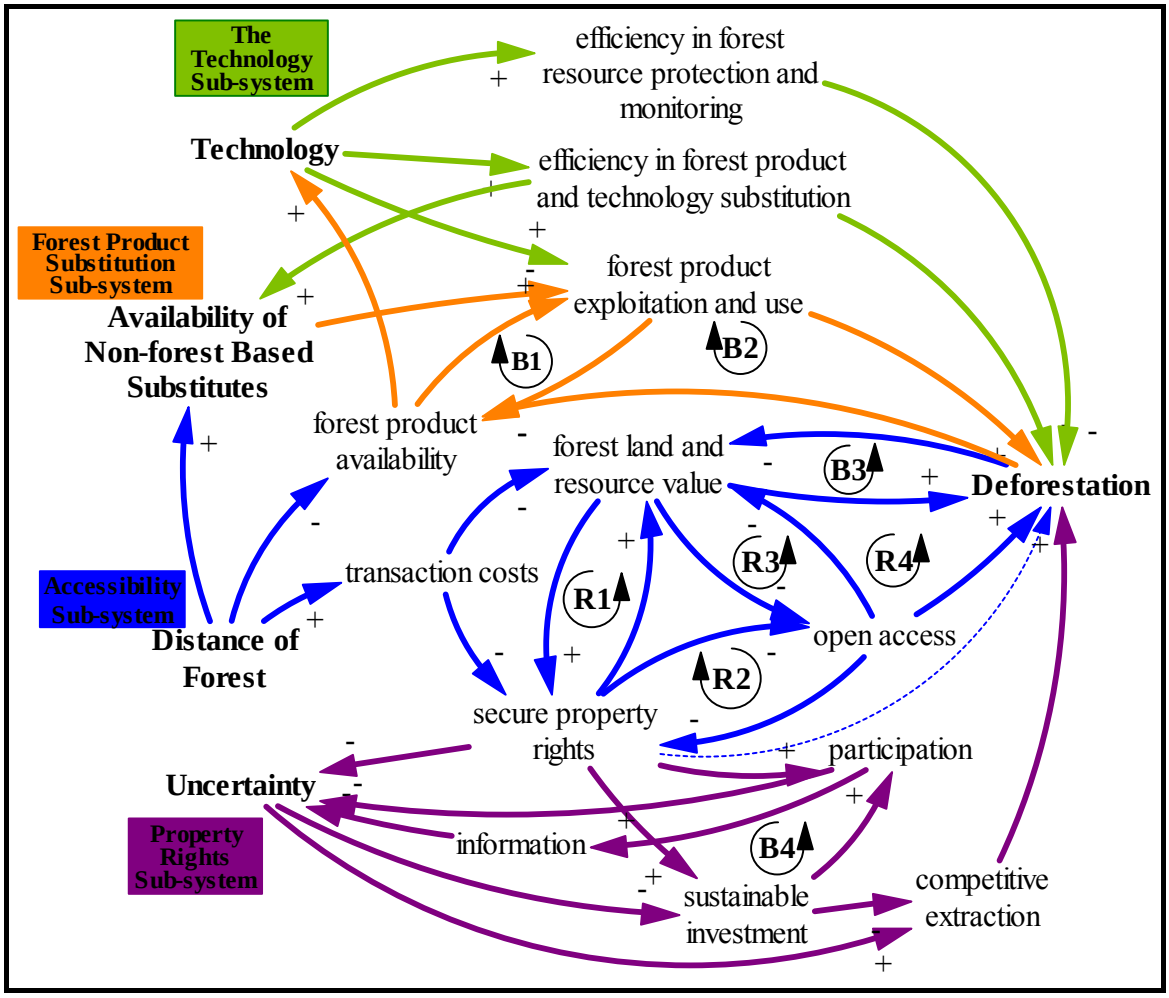

Figure 10: The Deforestation System, Showing Individual Subsystems.

The influence of each driver of deforestation could be markedly different from one case of deforestation to another or between different periods in the same case of deforestation. The Amazon can be used to illustrate how different drivers of deforestation influence the process at different times within the same landscape.[36]

When the Portuguese initiated their plan for the occupation of the Amazon in 1616, the establishment of sugar cane plantations and the extraction of forest products for the mainland market was not the topmost priority—it was rather the search for gold and precious stones. As a result, there was little deforestation associated with the two former activities since the full effort was not employed in developing them. Full scale deforestation was evident in areas like Mato Grosso and Goiás where gold was found and its extraction had to be maximized because of its high value. Hence besides the high value of gold compared to the value of forest resources which explains deforestation in these areas, there were also factors like the absence of political or community-based resistance to occupation that favored deforestation. After the discovery of rubber vulcanization by Goodyear, the period beginning in 1840 saw the introduction and

[36] Most of the literature for this account is adapted from Salati *et al.* (1990, pp. 484–489).

expansion of rubber in the Amazonian landscape. By this time, river traffic had been enhanced along the Amazon by increased exploration which led to a better knowledge of navigable ways. Since rubber offered better income value than sugar cane, areas that used to be under sugar cane plantations were put under rubber cultivation and vast portions of new forest lands were cleared to cultivate it. Hence, deforestation related to rubber cultivation was favored mainly by the high value for rubber as well as greater accessibility to the forest land and markets. Also, the Portuguese colonists were having a free hand on the forest resources and establishing the tenure system they chose, as indigenous Indians either migrated away from areas occupied by the newcomers or were killed. The era of coffee expansion saw the deforestation of north eastern highlands of the Amazon. Because of the income derived from coffee cultivation, the strength of deforestation was just as strong as it was during the rubber boom. Coffee however has never replaced rubber because the two crops grow in different ecological conditions. Since the 1950s, deforestation has been driven largely by growth in timber exploitation and in the conversion of forests to grazing land. This has been aided mainly by increased road infrastructure in the Amazon, government policy, system of land tenure arrangements, and others.

8 Policy Implications

Population growth and poverty seem to be the main causes thought to drive deforestation, at least in the tropical world where deforestation rates are high. This has significant implications on decision makers' perception of the problem and their enthusiasm of solving it (especially in areas where there is limited enthusiasm for solutions[37]). Many authorities and bodies with the task of fighting deforestation in these parts of the world are quick to point out how difficult it is to achieve their goal since it entails managing evasive conditions like population growth and poverty. They are fast in explaining how slow it is to witness positive changes in forest cover after applying measures that should control population growth and fight poverty. Hence, solutions to deforestation which have to respond to population growth and poverty are not to be expected in the short-run. Usually, such arguments are backed by few (if any) ambitious anti-deforestation measures. Adopting and propagating such arguments display the absence of a will or strategy to fight deforestation.

Putting aside the population growth and poverty tandem (which the methods used in this paper fail to identify as a cause for deforestation), much can be done that can yield more immediate results in the fight against deforestation.

(a) Decentralize control over forests. Since the 1970s, the decentralization of natural resource management has become fashionable for many governments around the world. Users of natural resources at local level have been encouraged in many ways to become more involved in the management of these resources. This move has been driven partly by governments recognizing the fact that they cannot adequately

[37] Examples of such areas are states where the ruling elite benefits from the illegal exploitation of forest resources and pay lip service to conservation initiatives—many parts of tropical Africa and Asia fall within this category. In other cases like in South America's Amazon, people see the forests as an obstacle to economic development and pressure governments to remove barriers for its exploitation.

manage, conserve and protect natural resources such as to ensure their sustainability even with the most ambitious management plans and forest protection and conservation bodies. This insufficient management and protection was leading to the degradation of forest resources in many parts of the world. It was also thought (and is still widely held) that participatory forest management (PFM) will lead to greater livelihood security, poverty reduction, greater local empowerment and improved forest governance.

(b) Stop providing incentives for deforestation. As discussed previously, subsidies for forest conversion into other land-uses, tax holidays for deforesting economic activities, and land tenure systems that encourage the clearing of forests do significantly reduce forest area. Rates of deforestation in the Amazonia would have been very different without them. The limited prosecution of offenders with forest degradation activities is in a way an incentive to undertake activities that degrade forests even more.

(c) The environmental impact assessment of development projects should be undertaken with greater rigor and their results taken seriously. As already seen, developments like transport infrastructure through forests could lead to a positive feedback process of deforestation. There is therefore need to properly evaluate the consequences of these projects before implementing them.

(d) Ensure security of forest property rights. This has been seen to reduce uncertainty and can permit greater investment in forest development. When property rights are secure, people can undertake investments in forests whose yields mature over the long-term but will live for the present (consume forest products with little or no investment) if there is no security of rights.

9 Conclusion

The traditional understanding of deforestation has in the recent past borrowed increasingly from the development of knowledge in different fields of academia. This has widened the scope of understanding of this phenomenon. Using causal loop diagramming (a tool of systems analysis) to develop a conceptual model of deforestation is driven by the need to understand the role different actors and factors play within this system. The outcome (an understanding of some of the vital sub-systems implicit in the deforestation system and how different components within them interact) does give added insights for remedial action. The complex picture that emerges and the different reinforcing and balancing loops they carry show the magnitude of the challenges that anti-deforestation managers face. The Hyde Model, from which the cause-effect relations draw inspiration, is in itself a mirror of the complexity that is characteristic of the deforestation system, linking everything from technology to politics and beyond. A conceptual model of this sort offers variables (but no quantitative data) to ‘explain’ the process of deforestation and therefore cries out for empirical applications.

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