Deforestation: Subverting Hardin's Tragedy

Mankind has, since its inception, relied on forests to provide for our welfare. Food, shelter, medicine, fuel, wood, carbon regulation, environmental buffering, climate stability, aesthetic pleasure: these are but a handful of resources and functions our forests provide. For millennia, they served as an openly accessible resource that could be utilized for personal gain—a *commons* in Garret Hardin's parlance (Hardin, 1968). Their scale was incommensurable: Their continued existence was guaranteed—or so we believed as we exploited them with impunity. Last year, we managed to clear about 40 football fields worth of trees every minute in the tropics, which amounts to 16 million hectares of annual tropical forest loss. (Brad, 2018). Deforestation is not a recent occurrence either; it is a corollary of our economic growth. Global forest loss was estimated at 4.9 (±1.3) million hectares (Frederic, et al., 2002) from 1990-1997, which is a third of the 2017 tropical forest loss estimates. Hardin would consider us forewarned. The ceaseless pursuit of our personal interests ahead of the larger social imperative to preserve our commons for posterity will inevitable lead us to mutual destruction. To subvert the inevitable, a course correction is needed—and technological solutions can only get us so far. To prevent an actualization of Hardin's Tragedy of the Commons, we need to go further. To that end, the paper explores a trans-national policy structure that incorporates international, regional and local communities while shifting the burden of policy enforcement on the developed nations. Used in conjunction with technological solutions like drone-based

afforestation, real-time satellite monitoring and DNA mapping-based supply chain verification, the structure provides a feasible implementation plan to tackle deforestation.

In his work, Hardin uses the term commons to refer to an openly accessible resource from which a user may derive some tangible benefit. Resource availability in a commons is finite and exploitability bounded. Beyond that, resource depletion inevitably occurs. It was in such a context that Hardin's tragedy arises: Individual Interest lies in the immediate economic benefit derived from the maximal exploitation of the resource with no consideration for the net impact on the commons themselves. This is the behavior expected of a rational, self-interest agent. Collective Interest, however, lies in limiting resource use at a level that allows for the continued existence of the commons in perpetuity. The ostensible irreconcilability between the two posits an inevitable tragedy. Technical solutions, according to Hardin, are insufficient on their own to subvert the tragedy. Hardin's solution rests in the production of "social arrangements that produce responsibility" (Hardin, 1968)— which he refers to as mutual coercion. I concur.

The issue of deforestation runs along a parallel vein to Hardin's predicament with our global forest system, with its relatively open accessibility, serving as the commons. Forests provide us with a variety of benefits. Around 750 million people live close to forests, out of which up to 500 million directly depend on forests for their livelihoods, while yet another 60 million indigenous people are wholly dependent on the forests (Food and Agricultural Organization of the United Nations, 2014). In such instances where individuals directly derive economic gain from the forests, such as with agriculture, logging, ranching and fuel production, the personal benefit to be drawn by individuals is apparent and tangible. Collective interest, on

the other hand, is not nearly as apparent. While we could conceptualize collective interest in terms of sustainment of current benefits well into the future, this view artificially limits the scope to local communities directly dependent on forest products for economic sustenance. Our forest systems are a global resource and their tertiary benefits like medicinal resources or carbon sequestration are beneficial to the global population at large. For instance, nearly half of the pharmacological compounds used in the treatment of cancer derive from natural sources (Newman & Cragg, 2007) which could be threatened by deforestation, putting future discoveries at risk. Deforestation also depletes the size of global carbon sinks. In 2016, tropical deforestation was linked to nearly 6 Giga-tones of CO_2 emissions, which would place it just behind the China and the United States as a global carbon emitter if it were a country (Gibbs, Harris, & Seymour, 2018). As an inextricable piece of the solution to global warming and climate regulation, and as a preservation environment for biodiversity and potentially life-saving compounds, the preservation of forest systems is in the collective interest of the entirety of human society.

According to Hardin, the rational, self-interested agent, would want to maximize the economic gain he derives from the forest through a cost-benefit analysis as it pertains to the moment with no gravitas ascribed to either the collective, or the future. And there is evidence corroborating this view. Within the Brazilian Amazon basin, cattle ranching is the largest cause of deforestation (Rivero, 2009) with an estimated 50% contribution to forest clearance in the region about half of which—or 25% of the total— is attributable to individual ranchers (Walker, Moran, & Anselin, 2000). In a bid to maximize their personal benefit, cattle ranchers are quite willing to cut down the commons for the fertile land it provides. In doing so they are acting the

part of the self-interested, rational agent, failing to realize that the fertility of the land only exists as a consequence of forest cover, which enables nutrient cycling within the soil substrate while simultaneously preventing nutrient run-off and soil erosion. Thus, following their use of the land, it will remain depleted, leading to sustained harm of the collective interest—and, in the long run, exhaustion of the commons itself along with its concomitant benefits. At this point, one may be tempted to consider an appeal to conscience as a means of tempering present exploitation rates; however, this would merely leave us in a 'double-bind' as Hardin suggested it would. Appeals to the conscience of individuals are actively thwarted by possibility of others exploiting the commons to greater affect while the conscientious actor stands by; in a zero-sum game as with deforestation, loss-aversion provides sufficient reason to pursue the path of maximal exploitation. The fact that a lot of individual farmers and ranchers in third world countries are well below the poverty line and hard pressed to provide for themselves and their families only exacerbates the issue. The solution lies elsewhere.

The technical realm would be a good place to start. To Hardin, a technical solution is one that hinges not on any fundamental change in human values or ideas of morality but is instead predicated on the techniques of the natural—and, I would add, computational—sciences. As we have previously established, deforestation is not a recent phenomenon. As of such we need solutions that not only mitigate future damage, but also act to unwind the damage we have already caused. Afforestation, then, would be a good place to start. Until now, its labor and time-intensive nature has prevented any truly large-scale afforestation efforts. The largest reforestation effort so far, involving NGOs like Conservation International, Brazil's Ministry of Environment and the World Bank, was announced last year. It aims to reforest 30,000 hectares

of land over the next six years (World Bank, 2017). While the 73 million trees they intend to plant sounds impressive, contextualizing it within the previously established 16 million hectares forest loss in the region in 2017 alone reveals the true scale of the operation: 0.2% of annual forest loss. Using modern technology like drones with autonomous geospatial analysis could speed things up exponentially. Unlike humans, they run into no access problems trying to navigate the amazon, nor do they experience fatigue. Companies like BioCarbon Engineering based in the UK have working products (BioCarbon Engineering, 2018) that are capable of such operations—autonomously. The deployment of swarms of autonomous drones would help increase the rate of afforestation, though, without further data, it is difficult to ascertain a quantitative factor. While the initial cost outlay to carry such efforts out at scale may pose issues, it can be overcome with partners like the World Bank or other international initiatives. The primary issue with afforestation as a solution is with forest regrowth times. With current technology, even trees genetically modified for fast growth such as those sold by AborGen, a leading GMO company, still take 8-10 years to hit initial maturity (ArborGen, 2018). Natural tree growth is orders of magnitude slower. Worse yet, depleted soil takes close to 50 years for renewal following afforestation efforts (Singh, Pandey, Bajrang, & R.R., 2012). Forest communities, whether human or flora and fauna, may never be restored. And on scale, the asymmetry between the immediacy of deforestation and half-century lead times on forest recovery augur poorly for afforestation as a potential solution.

Perhaps, then, the application of technical solutions is better suited to abating deforestation rates instead. To do so, we must consider both individual farmers and ranchers, as well as larger corporations and illegal actors responsible for deforestation. As per our

previous discussions, if individual cattle ranchers contribute to 25% of the Amazon Basin deforestation, then subsidies and aid to help them shift to more intensive ranching methods might reduce overall deforestation levels. By providing them with genetically modified cattle with higher yields along with fertilizers to help their existing pastures regenerate faster, they would need less land to appropriate the same yield. This would simply skew their utility function without requiring any change in their values or morality thereby qualifying as a technical solution in Hardin's terms. The issue here is exactly the same as with the appeal to conscience: Even if they can subsist on their current utilization of the commons, the thought of others gaining more from the commons by maximizing their exploitation rates while they sit by and watch tends to not bode well with the rational, self-interested actor. And thus, he too, maximally exploits the commons. Indeed, we have seen much of the same play out in Brazil over the years with research indicating a positive correlation between cattle yield and deforestation for pasture land (McManus, et al., 2016). Since the 1970s to 2010, even though productivity per cattle (measured in kg of yield per animal per year) and the gross herd size of ranchers across Brazil rose 30% and 20% respectively, the entry of foreign companies and the demand to export processed beef to the United States pushed farmers to expand further towards yet unutilized land. Previously high-concentration states for pastural activity like Mato Grosso saw a 10% reduction in herd size from 2005-2012, while northern states like Para saw an increase of herd size exceeding 35%. The message is clear: Even if more can be done with current resources, productivity enhancing products and techniques can be used to gain 'even-more' from virgin forests upstream.

Clearly, human nature then presents a barrier that cannot be surmounted with technical solutions alone. More effective policies need to be formulated, yes; but, more than that, they need to be effectively enforced. Hardin's social arrangements only work if they actually manage to alter the rational, self-interested actor's utility function at the ground level. With no enforcement, the foundational precept of mutual coercion collapses to an appeal to conscience since there is no real coercion—only its whispers.

In the Brazilian Amazon, the legal situation is particularly murky due to a poorly implemented land ownership system. The land, by default, belongs to the Government of Brazil, who then awards some sections of it individual land owners through legal deeds while mandating that 80% of it be set aside as legal forest reserve (Pablo, 2009). Properly, implemented, this land deed system could be used alongside Brazil's pre-existing satellite-based deforestation monitoring system (Popkin, 2016) to keep individuals in check and skew their utility function towards forest protection through the imposition of heavy fines. In fact, with the Global Forest Watch System developed by various NGOs in collaboration with Google, this can be done in real time—and with sufficient resolution to be effective for even small plots of lands owned by individuals (Petersen, Sargent, & Gibbes, 2017). The reality, however, is quite different. Land permits are haphazardly distributed and land-ownerships ledgers improperly maintained. As a consequence, land is not systematically bounded by permit regions, but is instead simply appropriated—often through the use of force (Barrionuevo, 2009). Enforcement is fallow enough that that the International Union for the Conservation of Nature colloquially refers to even designated protected regions within the Brazilian Amazon as 'paper-parks' (IUCN, 2005). The lack of enforcement in many countries is intentional with governmental agencies

beholden to the maximization of their personal gain by colluding with illegal logging interests. An Interpol Report estimates the cost of forestry related corruption, with its primary concentration in Latin American countries to be of the order of USD 29 billion (INTERPOL, 2016). And, as the INTERPOL report confirms, the lack of enforcement is pervasive, not selective. It permits everyone from the individual rancher to multinational logging corporations to act with impunity. Consequently, any non-technical solution that relies on local authorities to implement directives or disburse incentives will likely fail. Consequently, solutions need to take this into account and outsource enforcement and the application of incentive structures further upstream.

The burden of enforcement will, inevitably, have to be shifted to international coalitions like the G8 (an international coalition including the United States, China, Russia, Japan, UK, Germany, Canada and France) and any other international body like they decide to enlist in their efforts. Specifically, they can apply incentive/disincentive structures at two levels: Governmental and Corporate. Deforestation with its established links to carbon emissions and climate regulation is a global problem and should be dealt with, at least in part, on the global stage. For instance, in ratifying the Paris Climate Accord, Brazil committed to reach zero illegal deforestation by 2030 and restore 12 million hectares of forest (Mooney & Phillips, 2016). Unfortunately, none of it is legally binding or enforceable. The G8 has the power to change that by linking their economic support through for countries in deforestation hotspots like Brazil to quantifiable, time-constrained goals in curbing deforestation. It would be unprecedented, and politically infeasible, to predicate all economic support on such measures; thus, a better implementation pathway would be to link a country's global deforestation contribution to their

international borrowing rates though the governmental treasury markets. Additionally, the G8 can incentivize local conservation efforts by placing a monetary sum on the carbon sequestration effects provided by the tropical rainforests.

The second avenue for international enforcement is on the corporate level. Between the countries of the G8, over 50% of all global forest product exports can be accounted for (United Nations Food and Agricultural Oganization, 2016). As of such, the G8 can implement local regulations that allow corporations to be penalized heavily, not just for any illegally sourced forest products, but also for their suppliers failing to meet key deforestation reduction criteria like a reforestation quota. Indirectly, this incentivizes corporations to utilize technology like the Global Forest Watch Satellite System to track supplier land activity, and to help local producers and suppliers, in Brazil or elsewhere, implement technology like drone based replanting solutions.

In both cases, independent assessments by bodies like the UN Food and Agricultural Organization (FAO) will need to form the basis for determining whether a country has met its slated goals or corporation in need of penalization. With corporate misdemeanors, fines need to be applied in the corporation's home country where—presumably—legal enforcement is not as much of an issue as it is in countries like Brazil. Apart from using real-time satellite monitoring to accurately measure deforestation, supply chain auditing for timber has also become quite feasible as of late. Recent bioengineering developments have allowed for 70-98% identification rate of timber to local tree population clusters based on statistical inference from chloroplast DNA (Ng, Lee, & Tnah, 2017). While implementing this would require initial outlay in collecting source DNA samples from deforestation prone regions as references, the analysis is

specific enough to trace wood products back to local tree clusters

ancestor and will hence be in close geographic proximity. It would also allow importers in the developed world to accurately validate their supply chain and verify that the wood is actually originating from where their suppliers claim it does. And now, they will also have the financial incentives to take this precautionary measure.

With that being said, the issue of deforestation caused by individual farmers, ranchers and other small-scale operations still needs to be addressed. While the economic pressure on governments to meet deforestation, metrics is likely to prompt them into enforcing their dormant conservation laws. But, employing this method alone risks sacrificing the economic security of large swathes of the population that are economically dependent to the forest to make ends meet. A comprehensive solution needs to make locals part of the solution and not the problem. A shared responsibility model coupled with education could achieve just that.

Within any given forested region, there are pockets of low biological productivity with a low carbon-stock—that is to say, that their disappearance would, in comparison to any other clearing activity, cause a minimal contribution to deforestation and carbon emissions. These areas can be determined through satellite imaging and remote sensing techniques (Asner, V. N. Powell, Mascaro, & E. Knapp, 2010). Low carbon stock land can be distributed by local governments to farmers and ranchers for their personal and commercial use for a tenured period of, say, 5 years. These may be smaller plots than many of these farmers and ranchers are used to operation on, but this can be allayed by governmental subsidies for intensive production techniques including fertilizers, pesticide and even machinery. As part of the agreement, local community members can be educated on the importance of forest

conservation and given responsibility for conserving adjacent high-carbon stock lands: that is to actively protect them from deforestation. At the end of the tenure period, land parcel renewal will then be based on the efficacy of the local community in meeting their forest conservation metrics. This would actively enforce an incentive structure based on the idea of mutual coercion to align personal their personal interest (land use) with the collective interest in maintaining forest carbon stock while still providing support for their livelihoods. If everything works well, the money for the subsidies the local governments will be providing will effectively be coming from the international community thereby distributing the cost to all those who benefit from the forests: that is, everyone.

The multi-level incentive/disincentive-based solutions presented here rely on shifting the burden of regulatory framework development and legal enforcement upstream, and onto the shoulders of the world's most developed economies. Coupled with technological aids like real-time satellite imaging, drone-based reforestation, intensive farming technologies and DNA based auditing, this presents a feasible solution for immediate implementation. It certainly isn't perfect, but with a system as interconnected and dynamic as the global forests, there can be no perfect solution. What is imperative is that we act presently to begin the process of implementing some of the propositions. Legal and technological processes could take up to a decade to fully implement. In the meantime, deforestation continues; worse yet, the effects of deforestation produce self-accelerating vegetation-atmospheric feedback mechanisms (Zemp, CF, HM, & al, 2017). We kicked the first domino—and now the kinetic chain perpetuates itself, leading us to an actualization of Hardin's *Tragedy of the Commons*. Inaction is no longer a choice. [Word Count ≈ 3250]

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- Well-researched and integrated into a coherent multi-layer solution
- Hardin is incorporated naturally and all his ideas are addressed
- Drawbacks/pushbacks are nicely addressed