"Thinking Globally and Getting Others to Act Locally: Polycentricity and the Conservation of Biodiversity"

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(This draft, December 2000)

Abstract:

Protecting biodiversity involves two social dilemmas that are closely linked. A local dilemma where the local users of forests face where individual extraction of a resource might not produce an outcome for the group that is socially desirable because of the risks involved in CPR dilemmas. Self-governance and externally imposed institutions can be implemented to overcome this first dilemma. A second dilemma exists when the group extraction of resources from the forest affect the well-being of outsiders, namely, the stock and variety of biodiversity in the forest for which there is a demand in terms of existence and option values. State and non-state actors have emerged from international to local levels to reduce these impacts by implementing programs and introducing economic incentives to induce in the local users a change in their rate of extraction so that spillovers to outsiders are reduced. However these actors face a typical Principal-Agent problem when implementing their programs. The result is a complex system of actors and a set of vertical, horizontal and diagonal relations that create a polycentric system. This paper uses a simple economic model to describe and combine the two dilemmas, and studies the problem within the context of Colombia where there is a convergence of high biodiversity and high dependence by rural groups on resources, difficult state governance, and a shift towards decentralized systems of environmental management. The paper may contribute to expanding the implications and potentials of thinking of polycentric systems when studying these types of more complex problems.

[1] Thanks to financial and institutional support by the Workshop in Political Theory and Policy Analysis, Indiana University, during the year of 1999-2000 as a Visiting Scholar.

1. Introduction

The Colombian government entitled in February of 1998 a group of more than 100 organized communities with 700,000 hectares (about 1'730,000 acres) of land, mostly forested, and in one of the richest areas in the world in terms of biodiversity[2]. The land transfer generated wide debate at the time, and the results of the experiment could be evaluated only decades later. If economic and ecological researchers are up to the task, it will be crucial to evaluate if these 45,000 people in the Chocó region, after making use of the ecological goods and services from these forests for which they now have more rights than before, are better off than what they could have been without the entitlement of this land; and it will be also needed to evaluate if the rest of society within and outside Colombia will receive more, less or the same economic direct, indirect and option value benefits of these ecosystems in terms of biodiversity preserved or water resources and services. Further, if there was in fact a trade-off with losers and winners, the subjective evaluation will then be a political one between the rights of the users entitled with the land against those of external beneficiaries of the global community.

This land transfer probably generates good hopes for some, and concern for others both within the country, and internationally, and exemplifies the policy challenges of biodiversity conservation. Given that the economic benefits from conserving biodiversity in ecosystems like the tropical rain forests can be perceived by different social groups, and through different types of goods and services, the search for an institutional setting that promotes a socially desirable

[2] In fact several indigenous groups in the Colombian Amazon have received during the 1980s and 1990s land titles with ample rights and autonomy over the use of resources from natural areas.

outcome is a challenging task for policy making.

As I will argue, most of the uniqueness of the problem arises from the fact that the main sources of biodiversity loss are associated with small groups of households, rural poor in most cases, that face the dilemma of using common-pool resources; but the impacts of their actions generate significant spillover effects to others downstream (in space and time) regionally, nationally and internationally without a clear institutional setting that could coordinate the failure with low transaction costs. Neither a local commons approach, nor a global public goods approach can capture appropriately the complexity of the problem.

This paper is a small attempt in that direction. The evaluation of the current governance systems through the lens of polycentricity (Ostrom, 1999; Ostrom, Tiebout and Warren, 1961) seems to be a richer framework for designing better institutions to respond to the task. Further, the features of the biodiversity problem described above is recognized by these authors as posing greater challenges to such approach: *"More difficult problems for a polycentric political system are created when the provision of public goods cannot be confined to the boundaries of the existing units of government. These situations involving serious spillover effects are apt to provoke conflict between the various units in the system."* (Ostrom et.al 1961: 840).

Three elements converge to make the Colombian an interesting case for studying this problem. First, it is one of the richest countries in terms of biodiversity given that while holding only 0.7% of the planet's territory, it hosts 10% of the world's biodiversity[3]. Secondly, the environmental institutional system of this country has witnessed a radical transformation

[3] In fact the Chocó region, mentioned in the introduction, coincides with the region with the highest density of species per area worldwide

towards the decentralization of responsibilities with respect to resource and environmental management towards the regional and local levels and towards a more active participation of non-state actors, leaving at the national level few responsibilities[4]. And thirdly, the economic and political environments of this country bring to the problem a rich and complex set of factors that only until recently have been introduced in the economic and policy modeling of transaction costs and information asymmetries. Severe difficulties for monitoring and enforcing the law, violent conflicts and poverty in rural areas, which are specially correlated geographically[5] with the richest regions in terms of biodiversity, make the problem of rules enforcement and institutional design quite difficult. Although these three factors are specially acute, many countries that host important biodiversity resources also show problems of high transaction costs in enforcing state based solutions to the problem, and have also attempted at various degrees a process of decentralization in several areas of public goods provision, including natural resources (Lutz and Caldecott, 1996).

To address this problem, I will start by laying out a simple model of how a community uses a natural resource that provides private and public benefits. Such simple CPR model will then be enriched by introducing the problem of externalities to outsiders, e.g. biodiversity losses. This will give rise to two basic dilemmas, one local, other global, that cannot be addressed by simple command and control or market incentive solutions. The difficulty in regulating externally the local commons dilemma, and the difficulties of also internalizing the failures

[4] Interestingly however, the management of the national parks system, a key strategy for biodiversity conservation, remains highly centralized in Colombia.

[5] There is an amazing correlation between the map of protected natural areas and the conflict areas, which experts clearly associate with the difficulty of army forces to intervene militarily where high dense forests protect insurgent groups.

between outsiders and the local users will be addressed within an institutional framework in which we identify the actors and the social exchange relationships involved among them and between them and the ecosystems. Although the resulting game will be based on a mix of Principal-Agent(s) and CPR dilemma situations, the game-theoretical predictions based on purely selfish behavior by the actors will contrast with evidence that individuals may show a disposition to both cooperate with others in their community, and also will be willing to provide public good benefits from their actions so that outsiders benefit. However, certain institutional factors can affect the outcomes and alter the equilibrium, some of which have been emerging from experimental and field evidence. The paper will close by addressing the hypothesis that a polycentric system of governance might be a better approach to this particular problem, as opposed to a highly centralized or a highly decentralized system of governance that controls the use of a resource by a group so that they satisfy their own needs without threatening the rights and needs of others affected outside.

2. Two social dilemmas in preserving biodiversity

Social dilemmas where the individual and group objectives are in conflict usually involve a group externality that can be dealt with in many cases by the group endogenously, via the construction of self-governance institutions. In other cases it might be also plausible that an external intervention on the behavior of the group members does induce behavior that produces a socially efficient equilibrium. However, even if the coordination of actions within the group, through self-governed or externally imposed institutions, achieves outcomes that are close to a

Pareto optimal for the group, there might be cases where such local optimality still imposes externalities or spillover effects to others outside of the group. In such cases the local institutions might not be effective enough to produce a globally optimal solution to the problem. Such is the challenge of biodiversity, and the model that follows attempts to illustrate the two dilemmas involved.

a. The Social Dilemma 1: Managing the local commons.

The first level dilemma is no different from the classical CPR problem (See Figure 1). Given the ecological characteristics of most renewable resources, we can assume a concave function, TB(e), that describes the flow of economic benefits that a group can perceive from putting different levels of effort, e, into extracting a resource from the common-pool. The concavity of such function could be assumed to reach a maximum given the maximum sustainable yield that an ecosystem can produce in terms of biomass, and beyond which productivity decreases to the point of exhaustion or collapse. We can also assume that TB(e=0) > 0, given that the common-pool provides other types of ecological services even if no extraction of

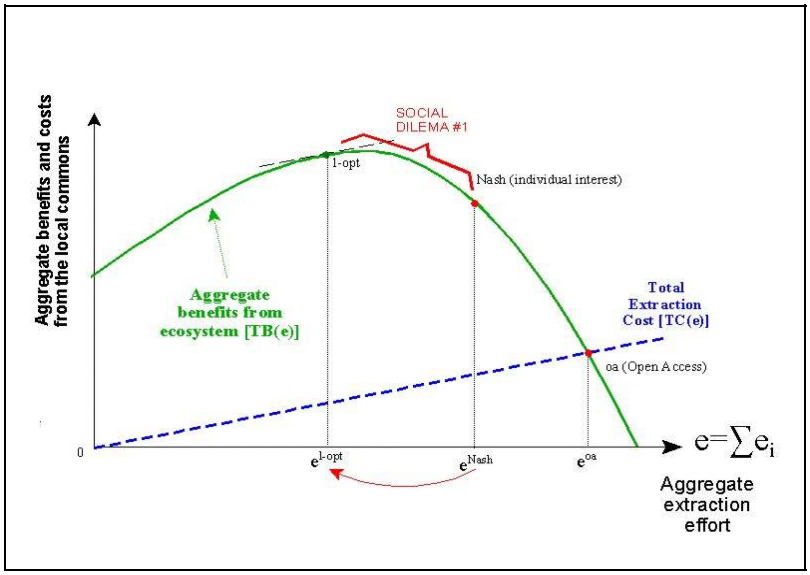

Figure 1. The CPR dilemma

resources happens (e.g. water regulation, pollinization, aesthetic services, nutrients recycling, erosion control, biodiversity conservation)[6].

If the effort of extracting the resource implies a cost for the group, TC(e), e.g. because of labor and other inputs, or just because of the opportunity cost of putting the effort into another income generating alternative, and if we assume for simplicity that the aggregate costs for the group increase constantly with effort, then we can define a level of effort $e^{l\text{-}opt}$ where the net benefits from the local commons are maximized (Fig. 1), i.e when marginal total benefits and marginal total costs are equal. Achieving such level of optimal effort, however, does not yield from the aggregation of non-cooperative actions of the group members. Since at $e^{l\text{-}opt}$ there are individual rents to be made from putting one additional unit of effort, individuals may find in their own interest to increase individual extraction[7]. Hardin's tragedy would predict that such increase by each individual would happen up to the point where the average individual benefits are equal to the average effort cost, that is, at e^{oa} where no rents can be drawn. However, Comes and Sandler (1983; 1986;1996) provide a game-theoretical analysis where the individuals may use strategically such conjecture about the behavior of others and therefore may find it rational not to increase extraction to such high levels, although still at inefficient ones. Depending on the functional form of TB(e), their Nash equilibrium prediction e^{nash} would shift to the left of e^{oa} in the graph[8].

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[6] Assuming TB(0)=0 does not invalidate the arguments that follow. It would reflects just a more simple case where the group can derive an economic benefit only if extracting a resource from the common-pool.

[7] At $e^{l\text{-}opt}$, any group member can still derive rents because the average benefit [$TB(e^{l\text{-}opt})/n$] are still greater than his average unit cost of effort.

[8] In their model, as the group size increases to large numbers the Nash and open access solutions converge.

We have then the first dilemma to solve. Individual rationality by maximizing the short run material payoffs would drive the level of extraction to levels socially inefficient and to pressures over the ecosystem, unless institutions are introduced to correct the failures. How institutions that emerge from the group or introduced in different forms affect individual behavior has been the subject of extensive empirical, theoretical and experimental research showing also that self-governance can be effective in solving this dilemma (Ostrom, 1990; Ostrom, Gardner and Walker, 1994; Baland and Platteau, 1996).

b. Social Dilemma 2: Spillovers on outsiders

But the focus of this paper is more on the next problem. Whatever the outcome is for the group's effort and the total benefits provided for the group, there will be a flow of externalities for people outside of the group. Excessive extraction can threaten wildlife and biological processes, and can produce downstream effects in terms of erosion, sedimentation and water availability. Low levels of extraction can produce the equivalent positive public goods for the same outsiders. In either case, these externalities cannot easily be subject to a contract and therefore can produce social losses. The case of biodiversity conservation in tropical rain forest areas is a typical case[9]. The international community seems to show a demand (willingness to pay) for guaranteeing the existence of the variety of species in these regions. If so, the they should be willing to transfer income to guarantee such benefits, or likewise, they should be willing to accept an economic compensation for the loss of such biodiversity if the group

[9] Indirect, option and existence values from different ecosystems are now widely recognized and valued economically with figures that are not anymore minor. Costanza et.al (1997) estimated the annual flow of services from the world´s natural capital in the neighborhood of 33 trillion dollars.

extracting the resource finds in its own interest to extract to levels that decrease biodiversity but maximizes the group's direct and indirect benefits even if overcoming their own CPR dilemma. At no point it is being argued here that the local users of the CPR do not consider in their preferences the types of benefits from biodiversity for which outsiders care. Local users do recognize, for instance, the option value of preserving resources even if it implies an opportunity cost of not extracting them for short-run benefits. However, the marginal utilities that an outsider and a group member show could be quite different, for instance, for one unit of an endangered species[10]. The opposite case would be for a species only known to the group to have medicinal value. Further, there might be income effects that make such differences even greater when valued at economic units, creating an upwards shifted demand or willingness to pay for preserving certain species for which both local users and outsiders show an option value of preserving.

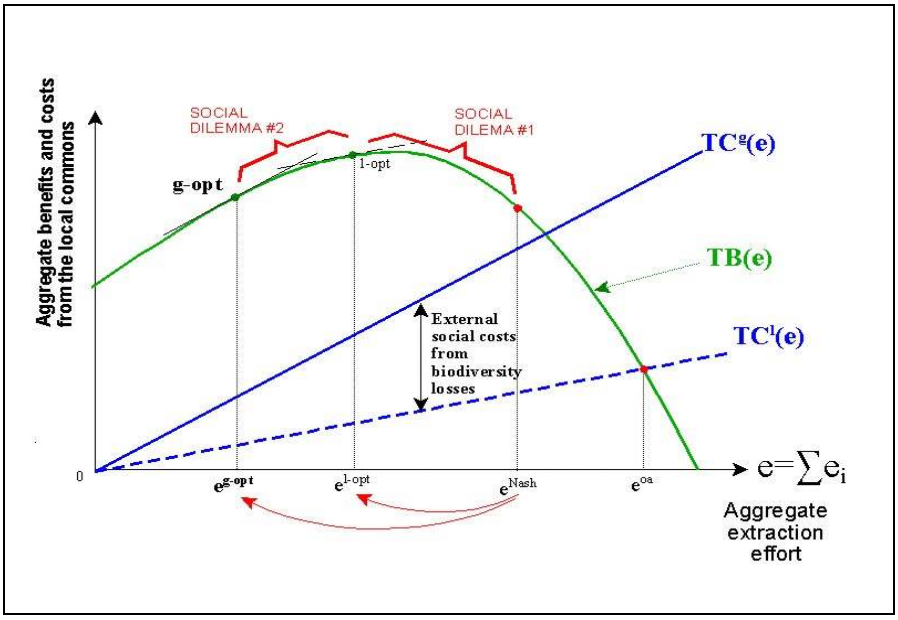

Figure 2. The second (global) dilemma of biodiversity.

[10] An extreme of this can be the marginal value placed on endangered species that pose a pest threat to local farmers´crops and livestock. The cases of elephants, foxes and wolves, and predator birds can be found worldwide.

To model this next dilemma, Figure 2 shows how we can introduce such spillover effects from biodiversity as an additional cost, external to the users which we can then add to the extraction costs in the spirit of the Pigouvian analysis of externalities (Pearce and Turner, 1990). As effort extracting increases, the pressure over the ecosystem reduces its biological resilience and productivity and therefore reduces its capacity to host the variety of species that had achieved at its climax levels. Such impacts might not affect as severely the production function and decision making by the group members, even if we assume that they have achieved their local optimality. But such external costs do affect the welfare of others whose preferences are a function of existing biodiversity in that commons.

Therefore, by adding the external costs to outsiders from the decrease in biodiversity, we can look for a global optimal level of extraction at $e^{g\text{-}opt}$ where global net benefits are maximized. Once again, if no contracts can be written between the user group and the outsiders to guarantee that a compensation is made to the users group if they choose a level of aggregate extraction lower than $e^{l\text{-}opt}$, or to the outsiders if the user group chooses to increase extraction above $e^{l\text{-}opt}$, there will be social losses.

In summary we have two dilemmas that seem to reflect a more realistic picture around the problem of biodiversity conservation. A local one (Social Dilemma 1), given that in many cases biodiversity resources are located in natural areas where there is joint access to extracting resources by a group creating a CPR type coordination failure. And there is the global one (Social Dilemma 2) where it is difficult to create institutions that internalize the external effect that the group´s level of extraction or conservation has on outsiders who show a demand for preserving biodiversity.

Much of the literature dealing with either problem ignores the relevance of their interdependence. The local commons or CPR literature in most cases assumes that the scope of the externalities arising from extraction remains within the welfare of the group members (Ostrom, 1990; Ostrom, Gardner and Walker, 1994; Bardhan, 1993). In the same fashion the local public goods literature originated by Tiebout´s (1956) model had to assume among others that no spillovers were created by the provision of a public good. On the other hand most of models and studies regarding the public goods problem of environmental pollution, biodiversity conservation and natural resource use assume that regulation happens between a regulator and a single decision-maker (polluter, resource user), and not between a regulator and a group of decision makers that face a group externality among themselves. An exception to this is found in Randhir and Lee (1996), who based on the basic Holmstrom (1979) approach of moral hazard, develop a model for studying the local commons problem under a principal-agent framework where effort by the users (agents) is unobservable to the governing institutions (principal).

By looking at a concrete case such as the institutional system of Colombia, we can describe in more detail the game that we have been attempting to build.

3. The National Environmental System in Colombia (SINA).

a. Background.

The current institutional system that governs the use and conservation of natural resources in Colombia consists of a series of actors (state, private and non-profit organizations), and a series of relationships among actors (coordination, regulation, funding, agreements), and

between actors and the resources (ownership and management, regulations over use and conservation, transfers of resources, and agreements). Before the institutional system was formally organized with the introduction of the Environmental Law 99 of 1993, most of these actors and relationships already existed[11] but there were enough coordination problems that pushed for a more coherent institutional system, along with the international pressure for many countries to organize their environmental sectors prior to or as a result of the 1992 Rio conference.

On the other hand, Colombia had been going through a radical transformation of the public sector towards the decentralization and devolution in the provision of public goods from the central to the state and specially to municipal levels, since 1986 when the first major law (Ley 12/1986) was passed beginning the transfer of significant resources and responsibilities to municipal levels, in key sectors like water provision and treatment, agricultural extension, health, roads, and education. Such transfer has been done gradually, sector by sector, for the last 15 years with a great variation of results across regions and across sectors. Nevertheless the political commitment and convincement at the time still seems alive that lower levels of provision of most of these local public goods can be done in a more cost-effective manner if the demand and supply functions are determined respectively by the local users and the municipal

[11] The existing legislation and the number of agencies responsible for forestry, water or soil resource management were already large by the end of the 1980s. Colombia passed one of the earliest and most comprehensive natural resources legal code in 1974. In terms of agencies responsibilities, for instance, the ministries of energy, transportation, health, and agriculture all had functions regarding water quality and management, but there was no coordination mechanism among them for such purposes. The Colombian National Park system, one of the oldest in Latin America dates back to the 1950s, but was under the ministry of agriculture and in direct conflict with the policy of agricultural frontier expansion dominant for much of the first three quarters of the century. For instance, for a farmer to legalize an ownership title by the Ministry, he had to prove that at least 2/3 of the land had been transformed as "improvements" (*mejoras*), namely, cleared and transformed into pastures or crops.

government along with non-state providers.

The next key step in this process was the results of an elected Constitutional Assembly that produced the New Constitution of 1991 (after the previous one from 1886) which reinforced and formalized the political and legal transformations towards a more decentralized public sector. Such Constitution is thought to be a very "green" one, where depending on the interpretation could have about 80 of its 400 articles directly relating to the environment[12]. During the election process for the delegates of the assembly the role that environmental groups played was crucial, and they showed that despite the lack of a so called "green" movement (Ecofondo, 1997), there was an important convergence of numerous but unorganized small efforts at the base aiming at introducing the environmental concerns into the new constitution.

However, the case of natural resources and environmental management has had a slightly different story. The so called SINA (National Environmental System) was born decentralized. The spirit of the New Constitution called for organizing a decentralized and participatory environmental sector as explicitly said in one of the articles of the text. The result of the debates from the Constitutional Assembly where the environmental debates were central, the pressures from the participation of Colombia in Rio 92, and the ongoing decentralization process converged into the Law 99 of 1993 which defines the rules and responsibilities of the actors and relations among them. While this allowed the sector to take advantage of not having to convert a highly bureaucratic and centralized government system of personnel, equipment and rules as in the case of most public goods sectors, the particular case of protecting biodiversity resources and

[12] One example of such commitment was introducing in the text the "ecological functions of property", namely, that individuals may see their property rights over a resource restricted , e.g. land, if found to have an ecological function that affected the rights of others.

wildlife management did showed such a situation. The existing National Parks Service had a history of at least three decades, highly inspired by the U.S. system, but with the differences of lacking resources and weak enforcement and governability over the territories marked as parks for conservation. Yet today such system has achieved, at least as *de jure* property rights, an allocation of almost 12% of the national territory into national natural parks, reserves and wildlife sanctuaries, one of the highest in Latin America.

The debate over decentralizing the national parks system continues today and very little has been taken away in terms of resources, control and responsibilities from the national government (Ministry of Environment). In the meantime the lower levels of governments (regional and municipal) have undertaken on their own actions with regard to wildlife and forestry conservation, in many cases beyond the responsibilities assigned to them but as a response to their constituencies.

Today we have a system of actors and responsibilities that include state actors (National Ministry of Environment, National Planning Department mainly; Regional Environmental Authoritis (Corporaciones Autónomas Regionales CARs; Municipal governments)[13]; non-state actors (NGOs: Non-Government organizations and non-profit foundations from international to national, regional and local; and CBOs: Community-Based Organizations that are local in scope by definition).

[13] For the particular case of Colombia the National level today holds very little responsabilities regarding the execution of policies which are in the hands of the CARs and municipal govemments, except for the case of the national parks system that remains highly centralized. Both CARs and Municipal governments have an additional element: they both democratic systems of electing their executive director (for CARs) and Mayor (for Muicipalities) who have limited powers and are overlooked by a general assembly and by a local council respectively. Also, CARs and municipalities have certain fiscal autonomy for allocation of resources, selection of personnel and planning devices.

b. Key relations and actors (A two social dilemmas game).

The basic problem is one where the local users choose a level of extraction ($e=\sum e_i$) of a resource from the local commons o CPR. Such extraction level determines the economic welfare of the users according to a concave function because of ecological constraints. On the other hand the level of extraction chosen by the local users affects negatively the welfare of outside beneficiaries who derive economic benefits from the conservation of biodiversity in the local commons. These outsiders include the other nationals and the international community who do not derive direct benefits from extracting biomass from the commons but who derive other indirect (e.g downstream) and option values from its conservation. To correct the social inefficiencies arising from local users using the resource and its effects on the welfare of these outsiders, we have external regulators/managers who do mainly two things. One, to directly own and manage natural areas to guarantee the protection of biodiversity and other ecological functions. And secondly, they use mechanisms such as command and control and economic incentives to induce in local users a change in behavior that is better aligned with the local and social optimal solutions described above. These external regulators can be state and non-state agents and for both types their goal is to internalize the externalities imposed by local users' over-extraction of the resource to outsiders.

Therefore we have at this point two interdependent economic puzzles. One, solving the commons or CPR dilemma among the local users because of their joint use of the resource and the externalities involved from their behavior (Social Dilemma 1 in Figure 2). The second challenge is the solution of the Social Dilemma 2 and can be better described as a Principal-

Agent(s)[14] problem.

Either by integrating vertically the property rights of the resource (through direct ownership and management), or by ways of controlling hierarchically lower levels of govemments and non-state agencies (through transfers, controls, incentives), these external actors attempt to increase the levels of conservation of forests (i.e increase biodiversity supply and demand) and reduce the levels of extraction by local users (i.e reduce biomass supply and demand). Notice that both state or non-state organizations do similar things, either nationalizing forested areas that before were common or open lands, which in the case of states was quite frequent during the second half of the century in an effort to assign state property rights over forests, or privatizing forested areas for conservation or special management in the case of international or national NGOs and private organizations more recently.

In the case of using incentives, both state and non-state actors introduce different mechanisms to induce a change in local users behavior. Examples include subsidies and technology assistance for energy substitution to reduce firewood dependence, taxes on volume extracted, quotas and technology limitations on extraction levels or species allowed, marketable extraction permits, among many others. In either of these mechanisms there are problems of asymmetric information which make compliance difficult or very costly to verify. In the case of directly owning and managing a forested area, similar problems of difficult enforceability and incomplete information create other kinds of principal-agent problems between the decision makers in the upper levels of government and the government officials in charge of enforcing

[14] The welfare of the principal, any state or non-state organization attempting to induce a sustainable use of the forest, depends on the sum of unobservable and costly contractible individual extraction efforts by the local users.

the property rights through exclusion and control over use[15].

Local users on the other hand may device self-governed institutions to solve the social dilemma 1, but not social dilemma 2. As said earlier, this does not mean that the local users do not care about, for instance, about biodiversity conservation. They do, and they internalize that into their accounting of the total benefits function, TB(e), either because they recognize that biodiversity is key to sustaining the ecosystem's health or because their preferences include the welfare of others outside the community as I show in section 4 of this paper[16]. However, any self-governed institution aimed at solving a social dilemma faces a second degree collective action problem of enforcing the rules and norms. Thus, the solution of the Social Dilemma 2 does depend on the outcome of the first and yet it is much more difficult to device a simple institution to coordinate the welfare of the outsiders and the welfare of group members.

c. A map of actors and relations.

The following diagram (Figure 3) maps how the actors interact with each other and also with the resource itself. In the bottom we have the set of forested areas of a country which include different types of property rights and management regimes including state parks, private and community holdings. The local users in the middle of the diagram relate to the forests by

[15] In the case of political conflicts in the field, forest guards have always found it difficult to enforce perfect compliance with exclusion rules and have to allow certain levels of entrance and extraction by local users, or in the case of corruption they choose deliberately to allow loggers to extract much higher amounts of resources.

[16] This is one reason I deviate from the classical CPR models where the group benefits function from using the CPR is based only on the market or consumption value of the units of resource extracted. If other ecosystem´s services, given a level of extraction of the resource, are taken into consideration in the decision-making of the users, then we have to modify the TB(e) function to include non-zero values of benefits for zero levels of extraction.

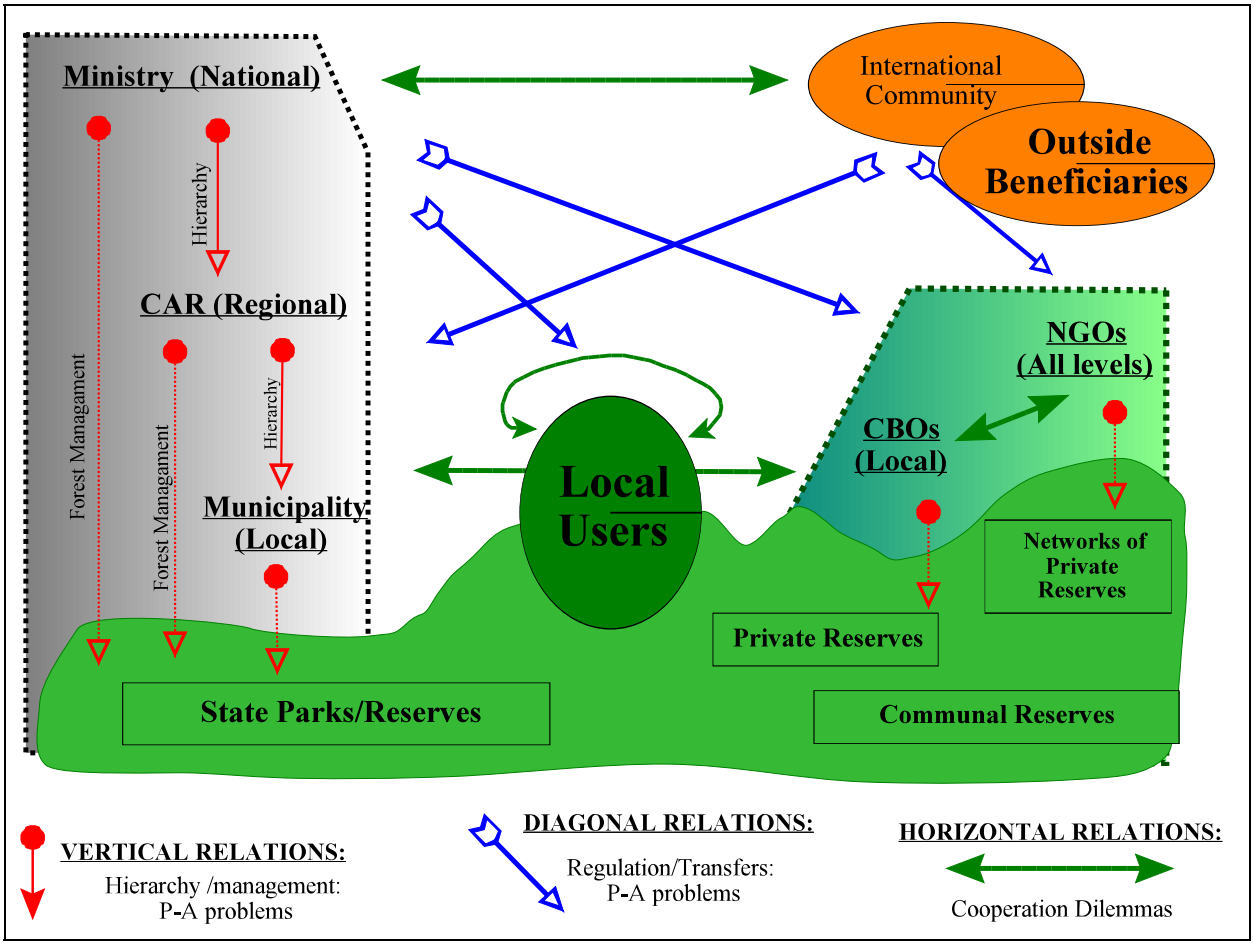

Figure 3. A map of actors and relations in the two dilemmas of biodiversity.

extracting a set of resources and benefitting from other ecological services. The left and right sides of the diagram show respectively the sets of state and non-state organizations that intervene in the problem by performing the two types of actions mentioned before: directly owning and managing forested areas, or by inducing changes in the behavior of the local users. And in the upper right corner we have the outside beneficiaries who basically use the state and non-state organizations as intermediaries of their well-being so that the impacts of the actions of the local users on the forests on them are minimized.

There different types of relations among these. We could classify the relations in three

types for purposes of the analysis. I will label the types as *vertical*, *horizontal* and *diagonal* relations, and provide examples in the diagram (Fig. 3).

By vertical relations I refer to hierarchical relations where authority is used to command from upper to lower levels a certain action. I include here the types of actions that the state agencies may undertake when directly managing forested areas or when commanding other agencies of lower levels to execute a certain policy or program. Such relationships also exist within the non-state organizations that use hierarchical relations and authority to command lower levels to undertake certain actions or programs. For instance, international non-profit organizations that have national and regional offices for direct management of protected forested areas they have purchased, or to conduct programs of assistance and research in certain regions.

In the case of diagonal relations I include the mechanisms that the state and non-state organizations use to induce changes in the way local users extract resources from the forests. From enforcing property rights to introducing economic transfers in terms of subsidies or taxes to controlling the type or level of extraction, these organizations, state and non-state, attempt to align the local and the global optimal levels of extraction $e^{l\text{-}opt}$ and $e^{g\text{-}opt}$ in Figure 2 by changing the relative prices of users with respect to the opportunity cost of extracting one unit of the resource.

And finally there are horizontal relations based mostly on mutual agreements of collaboration among actors to individually act in a way that produces a collective outcome that is Pareto optimal. This includes the case of the relations among the local users with respect to their own local welfare function, and also among local users, state, and non-state agencies who can share resources or join efforts to achieve certain goals on conservation. In the case of self-

governance institutions among local users we can include the Community-Based organizations (CBOs in the diagram) which I differentiate from the NGOs for obvious reasons. The CBOs are usually governed and formed by the local users while the NGO involve a significant amount of outsiders. Within these horizontal relations we can also include the so called co-production processes (Ostrom, 1996) and networking and `second order devolution`efforts (Bickers, 1999) where non-profit and state providers divide or combine efforts to increase the supply of the public good.

4. Polycentric Systems: Analysis of the vertical, diagonal and horizontal relations.

Polycentric systems involve different levels of governance and different types of state and non-state actors interacting in the production and provision of public goods (Ostrom, Tiebout and Warren, 1961; Ostrom, 1999). Different levels of governance allow to overcome the problems of spillovers and accountability that can emerge when the goods produced present problems of publicness. Different types of actors also allow to expand the supply by joining efforts and co-producing with other non-state actors, including the users themselves who are more than clients or recipients of the public good, and also increases accountability in the process (Ostrom, 1996). By studying in more detail the vertical, diagonal and horizontal relations, I propose, the analysis of polycentric systems can be enriched greatly. In general, these three relations try to solve the problems of cooperation, conflict and cooperation involved within the polycentric system (Ostrom, Tiebout, Warren, 1961)

Notice some key differences across the three type of relations. The vertical and diagonal

relations involve a Principal-Agent problem[17], while the horizontal relations involve basically a collective action dilemma[18].

a. Polycentric vertical relations[19].

In the case of vertical relations, the agents' action is the effort that local managers (state and non-state) of the protected forested areas put into enforcing property rights, i.e excluding local users from using the resource, or the effort into managing the forests[20]. Usually the principal and agents in this case establish a labor contract relationship in the case of direct management of forests by state or non-state agencies, or a control relationship in the case of superior levels of organizations monitoring performance of lower levels. But in either case the agents' effort is difficult to observe.

b. Polycentric diagonal relations.

In the case of the diagonal relations the Principal-Agent problem is different for three reasons. It involves a different agent, in fact a set of agents, the local users, it involves a different action by the agents (extraction of the resource in this case) and it does not involve a hierarchical (labor or control) relation but one in which the Principal induces a change in the behavior of the local users through different incentives such as regulations, rules or payments (e.g. taxes and

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[17] In the P-A problem the Principal wants the agent to perform an action that affects his utility function usually in a different direction that it affects the agent's. However the action performed by the agent cannot be observed and therefore cannot be contracted for by the Principal, creating the possibility of social inefficiencies.

[18] In a sense a CPR or n-person cooperation dilemma is a Principal-Agent(s) problem too. Each player (principal) wants the rest of the group members (agents) to act in a way that is beneficial to her but the direction of such action goes against the utility maximization of the agents. The action cannot be observed in a non-cooperative game and therefore the risks of Pareto inferior solutions.

[19] Przeworski (1996) describes in much more detail the types of Principal-Agent relations that exist in the design of the state and how citizens-voters relate in different ways to the government, judicial and elected units.

[20] I include here effort into afforestation, fencing, pruning, monitoring, seedlings, etc

subsidies). In this case the action that the agents choose, extracting the resource, affects in an opposite direction the utility of the Principal because higher extraction reduces the supply of biodiversity benefits for others outside the local users group.

c. Polycentric horizontal relations.

And finally there are the horizontal relations in which a typical commons or social dilemma emerges among the parties. In the case of the local users they face the CPR dilemma when deciding the effort put into extracting individually the resource. The other examples of horizontal relations are between producers/providers of the public good. State, NGOs and CBOs often and increasingly form partnerships to undertake projects for provision of public goods. In our particular case we can mention watershed management, forestry conservation and afforestation projects. In these partnerships there are however the same risks of collective action given that each partner would find it in their own interest in reducing the contribution to the project and gain from the contribution by the others given that there are no contracts to enforce the participation. Other institutional mechanisms have therefore to emerge to sustain cooperation in these partnerships.

There are cases in which state and non-state agents choose to induce changes in the behavior of other state and non-state agents through non-hierarchical relations but through e.g funding transfers. I would consider these as diagonal relations and not as horizontal, as shown in Figure 3.

d. Agency and cooperation problems for a polycentric system of governance.

The polycentric system faces the challenge of solving the two social dilemmas described in Figure 2 by defining the best set of institutions through a set of actors and relations described

in Figure 3. To do so it has to overcome the Principal-Agent and collective action problems described above. At the bottom of these problems is the individual decision-making of the local users who are ultimately the ones defining the outcome of their own well-being and that of the outside beneficiaries. If local users care only about the short run benefits from extracting biomass from the forest, or even if they extract at rates that sustain the biomass productivity over time but ignore the other types of ecological functions that the ecosystem provides for others downstream or in the future, the social dilemma 2 remains unsolved. However, there is no strong evidence that the local users in fact ignore these external benefits and that they do not have in their preferences some component of caring about the well-being of others because of their use of the forests. The next section deals with this question with empirical evidence from Colombia. Such evidence such provide an optimistic light for a polycentric system of governance that solves the two dilemmas if in fact the two are not as in much contradiction with each other.

5. Preserving biodiversity for others: Do they care?

In a recent household level survey to 600 people in three rural villages of Colombia (Cardenas, 2000) we found an interesting pattern regarding people´s willingness to cooperate in preserving biodiversity resources for their community, their fellow Colombians and the rest of people worldwide. Further, we applied a series of economic experiments in the field to also test in a less hypothetical way how much individuals who in their real life face daily a CPR dilemma, would behave in an equivalent experimental setting and what institutional factors

increased or decreased their cooperation in the dilemma[21].

In the same fashion that individuals do not seem to behave in economic experiments neither as purely selfish nor purely altruistic or unconditionally cooperative agents, the survey respondents seemed to be leaning towards preserving biodiversity for others, but specially if those benefitting were of the same nationality, as shown in the following two survey responses. The respondents were asked at some point in the survey two questions about reducing the use of a forest, and about preserving a forest for others. In both cases as in the rest of the survey, the questions referred to an "area ___" which in each of the villages corresponded to the actual place where most people extracted firewood, logging and other resources and for which there was joint access for households of that community, regardless of the property rights of the land. The first question referred to refraining from extracting part of the resources to provide benefits to others as follows:

> *From the following questions, mark with a (+) that with which you agree the most, and with a (-) that which you agree the least:*
>
> ( ) *"We should keep extracting the same quantity and variety of plants and animals from the _____ area for our own consumption and for selling".*
>
> ( ) *"We should refrain from extracting a part of these resources so that the new generations from this community have something for the future".*
>
> ( ) *"We should refrain from extracting any resources from this area so that the new generations from this community have something for the future".*

With this first question we wanted to focus on the first local problem, that of solving the tragedy of the commons by looking at how the respondents would balance the needs of current

[21] See Cardenas, Stranlund and Willis (2000) for the field experimental results regarding the case of regulating externally the use of the commons and the unexpected negative results of introducing an imperfect external control system.

generations to future ones, and how it related to trade-offs in extracting the resource. The second question was:

> *From the following questions, mark with a (+) that with which you agree the most, and with a (-) that which you agree the least:*
>
> *( ) "The variety of plants, trees and animals from the ____ area should be preserved so that this community and their descendants can enjoy it".*
>
> *( ) "The variety of plants, trees and animals from the ____ area should be preserved so that this community and other people of different regions in Colombia can enjoy it".*
>
> *( ) "The variety of plants, trees and animals from the ____ area should be preserved so that this community and other people from other countries besides Colombia can enjoy it".*

In this second question we wanted to focus on the second problem, the global one, where outsiders may benefit from the sustainable use of the resource or suffer from its over extraction.

Predictions: In both questions, a model of individual rationality based on the maximization of short run material payoffs would predict a decrease in the fraction of (+)s and an increase in the fraction of (-)s as one moves from the first to second to third sentences, given that these are typical examples of the "tragedy of commons" hypothesis in the first case, and of the voluntary contributions dilemma of public goods in the second. However, any deviation from such rationality model that includes other-regarding preferences and other kinds of institutional rules and norms should make the previous prediction weaker. In a sense these two questions explore respectively the inter and intra generational equity regarding biodiversity conservation. Inter generational equity (Question A) refers to the commons users' willingness to sacrifice short run income in order to sustain the biological productivity of the ecosystem for them and others in the future. Intra generational equity (Question B) instead relates to the users' willingness to preserve resources order to provide the public good to others in the community, or outside of it

at the national and international levels.

The complete tabulation of answers is presented in the following table[22]:

	Agree the Most - Marked (+)	Disagree the Most - Marked (-)
A. Willingness to reduce extraction to preserve resources for future generations		
A1. "We should keep extracting the same quantity and variety of plants and animals from the _____ area for our own consumption and for selling".	57 (13.1%)	378 (86.9%)
A2. "We should refrain from extracting part of these resources so that the new generations from this community have something for the future".	305 (70.4%)	128 (29.6%)
A3. "We should refrain from extracting any resources from this area so that the new generations from this community have something for the future".	157 (41.6%)	220 (58.4%)
B. About preserving biodiversity for others:		
B1. "The variety of plants, trees and animals from the _____ area should be preserved so that this community and their descendants can enjoy it".	406 (92.1%)	35 (7.9%)
B2. "The variety of plants, trees and animals from the _____ area should be preserved so that this community and other people of different regions in Colombia can enjoy it".	243 (63.3%)	141 (36.7%)
B3. "The variety of plants, trees and animals from the _____ area should be preserved so that this community and other people from other countries besides Colombia can enjoy it".	194 (46.6%)	222 (53.4%)

Survey results: These results deserve some close attention. First of all there seems to be no confirmation of the static homo-economicus prediction in the tragedy of the commons. First, the fractions of responses "agreeing the most" with phrases A3. and B3 (when there is a much higher foregone income to preserve the resource) are significant, and even higher if considering a better balance between extraction and conservation (options A2 and B2).

In studying the problem of voluntary provision of the public good for outsiders

[22] The total sample was 600 respondents; blank answers have been omitted.

benefitting from biodiversity conservation, the results are more complex. The strong feelings against "extracting the same amount for short run benefits to the community only" (A1) contrast with the strong feelings in favor of preserving the biodiversity for the benefit of the community and their descendants, as opposed to others. However, in terms of providing the public good to outsiders, there seems to be a slightly stronger feeling in favor of Colombians as opposed to the global community[23].

In brief, the results suggest a positive willingness to reduce extraction in order to provide biodiversity benefits for them and future generations deviating from Hardin's tragedy, and a recognition that others could and should benefit from the public good provided by preserving the biodiversity. These data support the notion that people's preferences do take into account the rights and welfare of others, including those that may not be able to contribute currently to the effort of conservation either from reducing extraction or contributing to a project of management. Further, the analysis of the data for these two questions is consistent with the results of an economic valuation exercise conducted during the interview in which individuals had to give a rating to a set of 'cards' representing scenarios of conservation projects each of which had a different combination of attributes represented in different levels of biodiversity and water conservation, and personal costs such as levels of allowed extraction of the resource, labor and cash contributions, and the type of manager and fraction of neighbors contributing to the project. The estimation results from that exercise showed also a positive and significant implicit

[23] As in several other rural regions in Colombia the political conflict between the government and both leftist and right-wing armed groups has created and reinforced a nationalist sentiment which has been recently agitated by the rumors and fears that international corporations are illegally entering tropical forested areas in search for biodiversity samples.

value for preserving biodiversity and for providing water benefits to them and others given the reduction in income involved in the alternatives.

6. Final and remaining questions.

Much of the analysis throughout the paper has used the case of Colombia as real setting to discuss the dilemmas, actors and relations involved in solving a complex public goods problem where the causes are local in nature but global in scope. Extending the analysis to other countries with similar problems in managing biodiversity might not be as difficult as many regions with similar contexts are facing equivalent systems of governance where state and non-state actors are intervening, and where national, regional and local levels play different roles. Other cases of providing similar public goods where at the local level we face a commons dilemma that produces spillovers to the global community are more difficult to find[24].

A polycentric system like the Colombian SINA involves limited powers and responsibilities by levels if we focus on the state actors only. This has caused controversy at all levels in the country. Sectors of the national level have warned sometimes that the regional CARs and Municipalities have excessive autonomy to make decisions over key resources of national strategic importance. The fiscal power of the national government over CARs is limited as most of resources of CAR and generated within their jurisdiction and constituencies. They have also highlighted the risks of CARs being highly politized by regional political leaders who

[24] The case of water management by local users and the impact in terms of sedimentation or water availability downstream is another similar case, although must of the spillovers affect only other regional or eventually national groups of society. Only a few cases involve trans-boundary watershed effects (U.S. Mexico border being one case, but less likely to involve the collective action dilemma among users upstream)

use the electoral and control procedures within CARs rules to their own goals. Municipalities on the other hand have often complained of the excessive intervention of their environmental actions by the Regional CARs on their local environmental affairs. However, such limited powers within the system can be read through Vincent Ostrom's lens of polycentric systems of governance in a more optimistic view: "*The maintenance of any pattern of social organization depends upon the potential use of sanctions by some decision makers to enforce legal relationships among other decision makers. Thus, an unequal distribution of decision-making capabilities must necessarily exist in any political system.*" (Ostrom, 1999: 55). Such would be the case for the vertical relations above. Further, similar arguments can be made for the diagonal relations between state and non-state actors.

Conflict arises when the provision of the public goods affects others beyond the unit of government providing them (Ostrom et.al 1961). The possibility that more than one state actor and more than one non-state actor can affect the outcomes by providing the public goods of biodiversity or by affecting the decision-making of local users, creates competition over political and economic gains, and such competition (vertical, horizontal and diagonal) is healthy for the system. The possibility of cooperation among them that we see in the increasing number of partnerships, networking and 'second order devolutions' (Bickers, 1999) is another healthy sign for biodiversity conservation through a polycentric system.

The challenge of an effective policy design is to introduce the institutional incentives that solve for the two dilemmas, local and global. However, these cannot be addressed separately. It seems that overcoming the global one requires the local one to be solved; however, the transaction costs for the outsiders to intervene in solving the CPR dilemma among users would

be high. Matters of national sovereignty, for instance, could make it difficult for the international community to intervene in the decisions by groups who have property rights over their resources, and that conflict has recurrently emerged in the negotiations of conventions on biodiversity, biosafety, patenting and others related.

a. Cross-effects and crowding-out of horizontal cooperation by introducing vertical or diagonal mechanisms.

Bendor and Mookherjee (1987) argue that when there are risks for collective action to fail because monitoring among group members is imperfect, the introduction of centralized mechanisms to control free-riding in the collective action situation might be desirable to combine the best both centralized and decentralized worlds. There are however remaining questions about possible cross-effects where trying to solve one of the dilemmas may have an undesirable impact on the resolution of other, given the high transaction costs in solving either the Principal-Agent problems or the Collective Action dilemmas involved in the relations. Rossi and Warglien (2000) studied a similar situation in a Principal-MultiAgent experiment where a boss (the principal) offers a share of the pie that a team of two workers (agents) have to produce through a game involving a prisoners dilemma. His results show that as the share offered by the principal to the workers is smaller, higher rates of mutual defection occur among the agents and therefore a smaller pie is produced. Their results reject the Nash predictions that the Principal should not share with the two agents much of the pie produced, and that workers should not cooperate with one another. Further, fairness by the principal seem to induce cooperative behavior on the two agents. Fehr and Gachter (2000), using a trust game setting with a Principal-

Agent model of labor relations, provide evidence that when principals and agents face an incentive based contract to be enforced and which punishes defection, the voluntary rate of cooperation decreases as compared to games where no incentive contract is involved.

In an field experimental design where subjects are real world CPR users we applied an external regulation on the behavior of individuals who face a 8-person CPR game and show how the introduction of a probabilistic penalty on non-compliance with the social optimal norm, aimed at increasing the group gains, in fact decreased the rate of cooperation that existed before any institution was introduced and performed much worse than the introduction of face-to-face communication (Cardenas et.al, 2000); Using a similar CPR design, Schmitt, Swope and Walker (1999) showed how excluding 2 of the 8 players from the face-to-face communication created inefficiencies because monitoring within the group became more incomplete and over-appropriation of the CPR could be blamed on those outside of the discussion even though group members would strategically over-extract. We have along our discussion a local and global community, and even though the local group of users may have institutions to coordinate their actions endogenously, the outsiders would find it very difficult to participate in those institutions unless they participate through the diagonal and vertical relations we have mentioned.

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