Including Ecosystem Services in Mitigation

A Report to the Colombian Ministry of Environment, Mines and Territorial Development
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This report presents a framework for including ecosystem services in mitigation for activities permitted in all natural resource sectors. In addition, we present a case demonstration of the framework for proposed coal mining activities in the Cesar Department. Throughout this document, we present the general mitigation framework for ecosystem services, then give details of the Cesar demonstration case in green boxes.

Framework for Including Ecosystem Services in Mitigation

The Colombian national government has established the requirement for mitigating and compensating for environmental impacts in Decree 1220 of 2005. In this decree, actions are required to restore the negative impacts of development actions to communities, regions, localities and the natural environment. In a recent action, the Ministry of the Environment adopted recommendations from The Nature Conservancy on how to avoid, minimize and compensate for impacts to the natural environment. However, there is still no clear guidance on how to account for and return or compensate the negative impacts communities experience as a result of environmental degradation during development.

Here, we propose a four-step process for applying the common mitigation hierarchy to ecosystem services, the benefits people receive from nature, as a way to account for and compensate impacts to communities. We follow the steps of the mitigation hierarchy: 1) avoiding an impact altogether by not taking a certain action or parts of an action; 2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; 3) reducing impacts over time by repairing, rehabilitating, or restoring the affected environment or by preservation and maintenance operations on-site during the life of the action; and 4) compensating for the impact by replacing or providing substitute resources or environments (e.g. CEQ 2000; ten Kate et al. 2004; Keisecker et al. 2010). We present the first framework that makes the ideas of mitigation operational for ecosystem services. As such, the Ministry is at the forefront of mitigation activities, and the framework provided here should be seen as a starting point for evolution as the field grows and science and methodologies improve.

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Cesar Department Case Study

We applied the expanded mitigation hierarchy for including ecosystem services to the case of proposed coal mining activities in the Cesar Department. This demonstration shows the flexibility of the framework and the kinds of results generated at each step. The Cesar Department covers 22,905 km^2 (Fig. 1a) and has been the leading coal-producing region since 2004. Current coal production comes from 17 granted mining permits (Fig. 1b), while additional permits are in the approval process (Fig. 1c). As such, coal mining has environmental impacts on the region that are likely to increase, and provides a major opportunity for expanding the mitigation hierarchy.

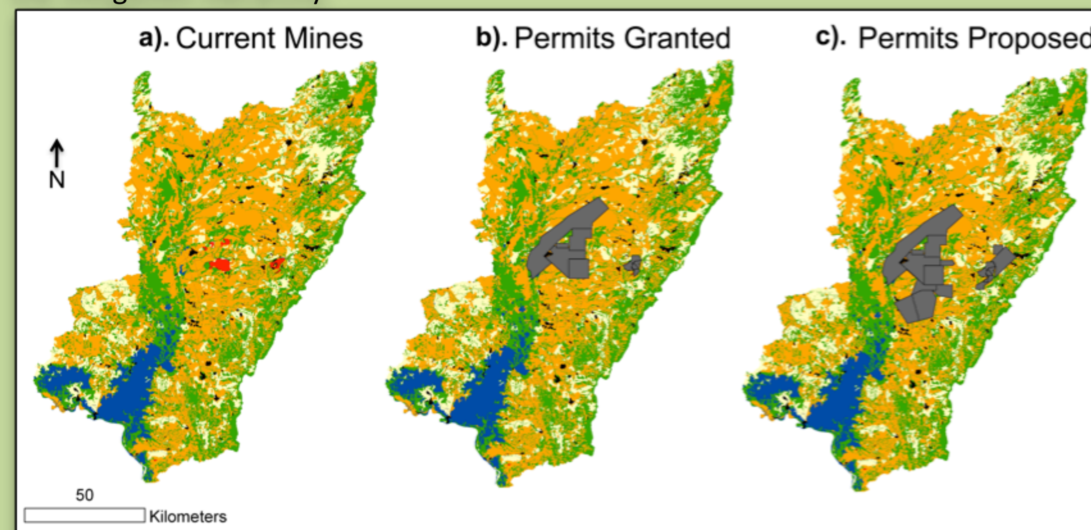


Figure 1. The Cesar River Watershed. Red areas (a) show the extent of current coal mining activities. Green areas show native vegetation, orange show agricultural lands, yellow show pasture and blue shows open water. The grey areas show the full extent of granted coal mining permits (b) and proposed coal mining permits (c).

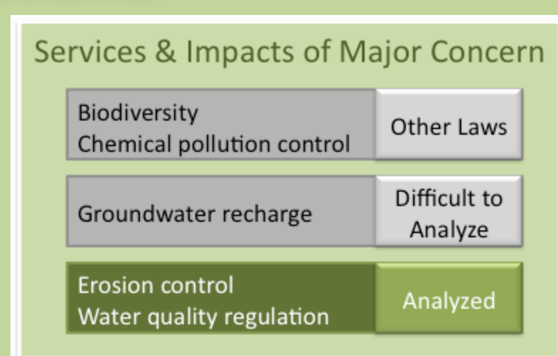
The Cesar Department boundary closely follows the watershed of the Cesar River, which flows from northeast to southwest and drains into the Zapatosa wetland, before joining the Magdalena River, one of the principal large river basins in the country. Remaining native habitats include the mountainous northern Sierra Nevada de Santa Marta Ecoregion with altitudes from 200 to 5,775 meters above level, rich in tropical Andean species and source of eight rivers that irrigate the Cesar Valley and drain into the Zapatosa wetland. In the west the Perija Range extends to the border with Venezuela and is primarily covered by forest of very high biodiversity value. The central and south areas of the department are occupied by the Cesar Valley Ecoregion with fertile soils where important productive activities take place including cattle ranching agriculture and mining. The Zapatosa wetlands are an important source of food security (protein from fish) and flood control. The Magdalena River ecoergion connects the central valley and the wetlands and has highly productive soils that support the most important agricultural activities in the Department.

Step 1: Identify services, beneficiaries and servicesheds of interest

The first step is to identify key ecosystem services and beneficiaries (communities). It is unlikely that all ecosystem services and communities will be accounted for in the context of impact assessment due to methodology, data and time limitations. A subset of services and beneficiaries may be selected based on a predicted high level of impact, a high social preference for a service (e.g. clean water) or a community (e.g. an indigenous community, a large metropolitan area, a major hydropower plant), correspondence with other existing regulations that prioritize specific services (such as clean water for drinking), commercial interest in the continued delivery of services (such as agricultural or hydropower production), correspondence with other ecosystem services or locations that will not be assessed, correspondence with biodiversity conservation priorities, or other factors.

Focal Services in the Cesar Department

In the Cesar case, there are several ecosystem services of interest that are likely to be impacted by coal extraction *and that are not regulated by other legislation*. The removal of vegetation and topsoil in the creation of open pit mines likely leads to the loss of carbon sequestration, erosion control (that improves drinking water quality and the lifetime of downstream infrastructure), surface water flow (for drinking, irrigation, recreation, etc.), flood regulation, and groundwater recharge (for drinking), among others. The provision of clean drinking water is of primary interest in this region. Most cities in the watershed, get their drinking water primarily from groundwater wells. However, expected drawdown of groundwater from mine-related pumping will make it groundwater use impractical and shift reliance to surface water (J. Gonzalez pers. comm.).



We chose a subset of services to include in this initial analysis based on 1) our ability to quantitatively assess impacts, 2) the likely sensitivity of services to mining activities, and 3) the relative importance of services in the region. As mentioned above, clean drinking water is of primary interest. Given the complexity of groundwater-surface water interactions, and the lack of freely-available information on the boundaries of aquifers in the region, we cannot assess impacts on groundwater in this analysis. Based on these limitations and the assumption that further aquifer drawdown will lead people to rely on surface water sources, we have assessed the impacts of mining activities on two components of **surface water quality regulation: sediment and nitrogen pollution control**. Other services could be added in future analyses as information and resources become more available.

Once the key services of interest and their recipient communities have been chosen, their 'servicesheds' can be identified. If environmental policies are to return the same services to the same people (as stated in Decree 1220), then we must know where people get their services from to ensure that eco-compensation returns the same benefits to the same people. To allow for the identification of such areas, we introduce the concept of 'servicesheds,' or areas that provide a specific service to a specific beneficiary. For some services, such as carbon sequestration, the serviceshed is the globe since the atmosphere is well mixed and carbon sequestration anywhere on the planet benefits all people. For other services, such as surface water-related services (such as drinking water supply, hydropower supply, water purification, flood mitigation, erosion control, etc.), the serviceshed is more localized, and consists of the catchment area upstream of the population or beneficiary of interest. Considering ecosystem service mitigation and compensation without this framework is very likely to redistribute the flow of services across the landscape, unintentionally creating ecosystem service 'winners' and 'losers.'

Beneficiaries and Servicesheds in the Cesar Department

In the Cesar case, beneficiaries were identified as the collection of towns within the study site that lie near rivers downstream of proposed mining areas. Of the 49 towns in the department (2005 total population = 878,437), 23 will be impacted by at least one mining option (67,227 people). We considered towns to be impacted if they fell directly within the boundaries of a proposed mine, or if a proposed mine fell upstream of the town in the same watershed. Some of the towns that will be impacted lie very close to their upper watershed boundary, so the serviceshed is extremely small and provides no real potential for mitigating impacts to the same beneficiaries (Pueblo Regado, Agua Fria, La Aurora, total popn 1,689). The beneficiaries we did analyze are shown in Fig. 2. We used the inlet of the Zapatosa wetland to represent the towns surrounding it, including Antequera, Belen, Candelaria, Chimichagua, El Trebol, Hojancha, La Mata, Saloa, San Jose, Sempegua, Soledad and Zapatosa. We considered the town of El Cerrito at the bottom of the basin as indicative of impacts to the town itself and to all downstream cities.

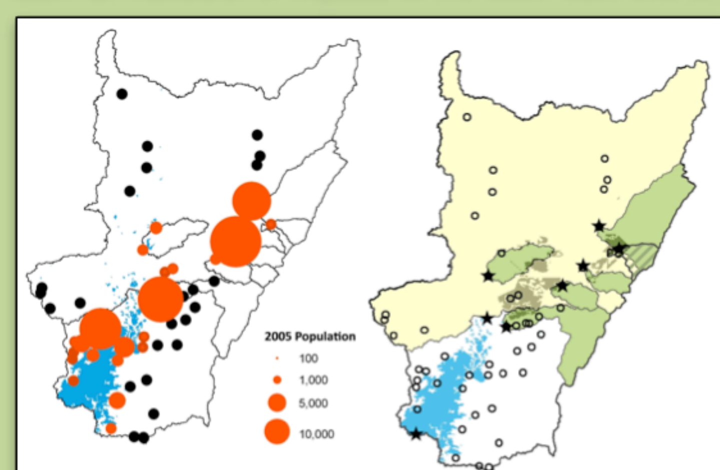


Figure 2. Cities in the Cesar Department. Those in orange in the left hand panel will be impacted by at least one mining scenario. Those shown as stars in the right hand panel were analyzed in this study. Servicesheds for each analyzed city are also shown at right. The yellow watershed is the serviceshed for all cities on the Zapatosa wetland (in blue).

Step 2: Identify options for avoiding and minimizing

Development activities will not be equally profitable or lead to equal ecosystem service impacts in all places. Given this variability, planners should identify, and avoid or minimize, impacts in places where impacts will be highest. If information is available on revenues, planners may want to minimize impacts in places where revenues from the proposed activity would be relatively low, but impacts would be relatively high. Areas for avoidance could also be high biodiversity priority areas, high ecosystem service areas, or a combination of both. No methods have been established for consistently identifying high ecosystem service priority areas for avoidance, but these methods are in development.

Avoiding Impacts in the Cesar Department

While no methods currently exist for identifying high ecosystem priority areas for avoiding impacts, Colombian law now requires that biodiversity priority areas be avoided. Our first approach in the Cesar demonstration case was to include those biodiversity priority areas as avoidance areas for ecosystem service provision as well (Fig. 3). This approach gives additional credit to the avoidance of biodiversity areas as saving native habitat is certain to provide some returns in ecosystem services as well. However, there is not perfect overlap between biodiversity and ecosystem service provision areas, so as methods are developed to identify ecosystem service priority areas, these should also be avoided in the granting of permits.

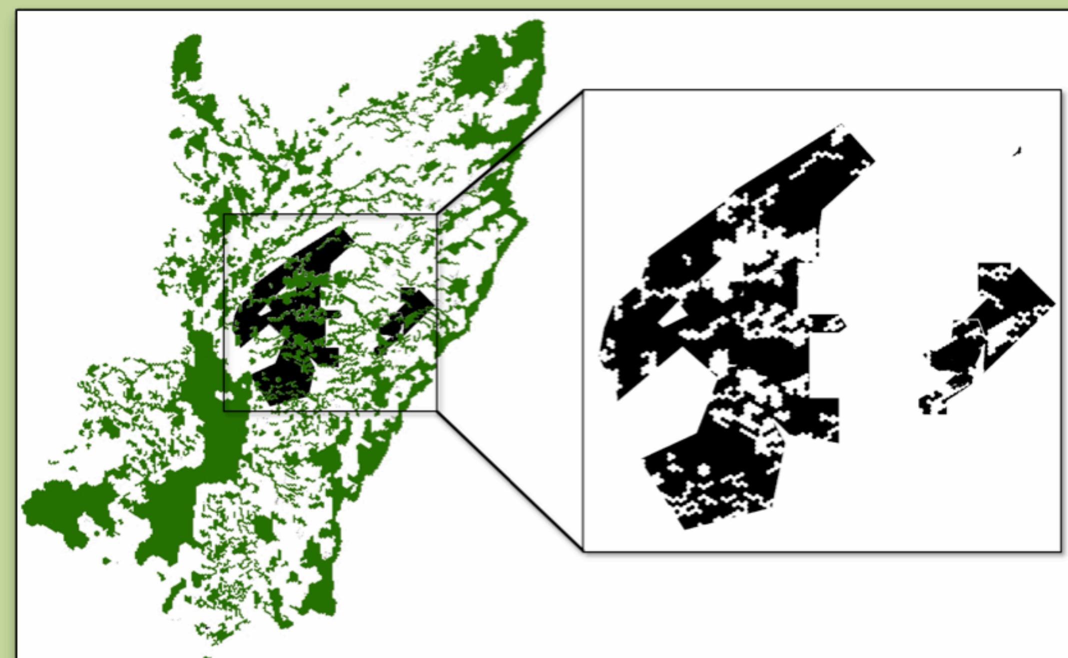


Figure 3.The biodiversity impact avoidance areas (green) recognized by existing law. We recommend avoiding these areas for ecosystem service impacts as well, and removed them from the proposed mining areas for assessment in later steps (inset at right).

Step 3: Identify options for reducing impacts over time

Some impacts of development activities can be mitigated in the project area as project activities change over time. Activities include reduction of impacts up front through best management practices, and on-site maintenance, restoration and rehabilitation. This kind of mitigation is feasible for activities such as oil and gas extraction, as exploration activities may be localized within a larger permit region. However, mitigation on-site will not be possible in all circumstances. Guidance for best management practices and recovery activities have not been developed for a large suite of important ecosystem services.

Reducing and Impacts in the Cesar Department

In the Cesar Department, open pit coal mining typically offers few opportunities for improving on-site environmental conditions during extractive activities. However, some improvements may be possible through on-site treatment approaches such as on-site water treatment technologies, settling ponds and other erosion control methods to reduce off-site impacts. These should be implemented as much as possible, especially for the control of pollutants that cannot be mitigated by the natural downstream environment (e.g. heavy metals).

Step 4: **Identify options for compensation**

As the last step in the mitigation hierarchy, impacts that cannot be addressed by any previous steps can be addressed by replacing or providing substitute resources or environments that offset the ecosystem service impact. The steps in identifying options for compensation are 1) estimate impacts of proposed activities, 2) apply a mitigation ratio and 3) estimate the potential for compensation via protection and/or restoration activities. Each is addressed in more detail below.

Estimate impacts of proposed activities

In ecosystem service impact assessment, the core question is how much impact will each beneficiary receive? Ideally, we would have observed data on how much an ecosystem service will change from a proposed activity in the area of interest. Often, such data are not available, so we can use simple models to estimate how much impact is likely to be received by each beneficiary. Even simpler methods of impact estimation are in development.

In some cases, the Ministry may want to avoid impacts to particular social groups. Since the beneficiaries of each service have been identified in Step 1, the impact assessment step can identify how much impact will flow to social groups of particular concern if demographic or socio-economic data are available. For example, the government may want to particularly avoid impacts on clean water provision for the poorest people in a region or for an indigenous group. If the poor or indigenous can be identified (with data on income, education, unsatisfied basic needs, or ethnicity, etc.), and their connections to ecosystem services tracked (with data on institutions and in some cases, infrastructure), then impacts on the poor can be estimated (Tallis et al. 2011).

Estimating Unavoidable Impacts in the Cesar Department

To estimate the impacts of the two proposed mining expansion scenarios in the Cesar Department, we used InVEST, a freely available software package that models ecosystem service change (http://naturalcapitalproject.org/InVEST.html; Nelson et al. 2009; Tallis and Polasky 2009; Tallis et al. 2011; Karieva et al. 2011). We used the water purification model to assess impacts on nitrogen pollution and the avoided sedimentation model to assess impacts on erosion control. These models were developed to use the simplest possible approach to modeling complex processes as a way to provide sound scientific estimates while requiring minimal data, time and resources to apply.

The water purification model estimates the annual average amount of phosphorus pollution and retention based on data concerning land use and land cover, elevation, precipitation, rainfall seasonality, evapotranspiration, root depth, export coefficients, uptake efficiency (the relative ability of plants and soils to take up, absorb and cycle nitrogen or phosphorous) and soil characteristics (plant available water content, effective soil depth). The avoided reservoir sedimentation model predicts annual average levels of erosion and erosion control based on improvements to the widely used Universal Soil Loss Equation. This InVEST model requires data on land use and land cover, elevation, rainfall erosivity, soil erodability, factors that represent the effects of vegetation type and management practices on soil erosion processes (crop factor and management factor), and retention efficiency (the relative ability of plants and soils to retain sediment eroded from upstream areas).

These models also have the capacity to give estimates of the economic value of these and other ecosystems services (hydropower production, carbon sequestration, timber production, crop pollination, fisheries, aquaculture, recreation). However, we focused on biophysical estimates of ecosystem service change because economic data were not consistently available for the region.

We calculated likely mining impact under each of the mining scenarios as the difference between nutrient (total nitrogen) export or erosion in each scenario and the current landscape. Resulting nitrogen pollution impacts are fairly evenly distributed across the landscape (Fig. 4). This means that the impact of mine placement is not heavily influenced by biophysical characteristics such as soil type, slope, elevation, and rainfall However, erosion impacts are higher in the eastern portion of the region in both scenarios (Fig. 4). High erosion impacts there result from a combination of slope and current vegetation cover. The eastern portion of the Cesar River watershed is bounded by the Sierra Nevada de Santa Marta mountain range with steep slopes. Steep areas that are converted are much more likely to lose soil than flat areas. In addition, this mountainous area has some of the last remaining forested area in the basin (Fig. 1). Forests are better than many other vegetation types (such as agricultural lands) at retaining soil, so the loss of forest vegetation leads to a larger change in erosion control.

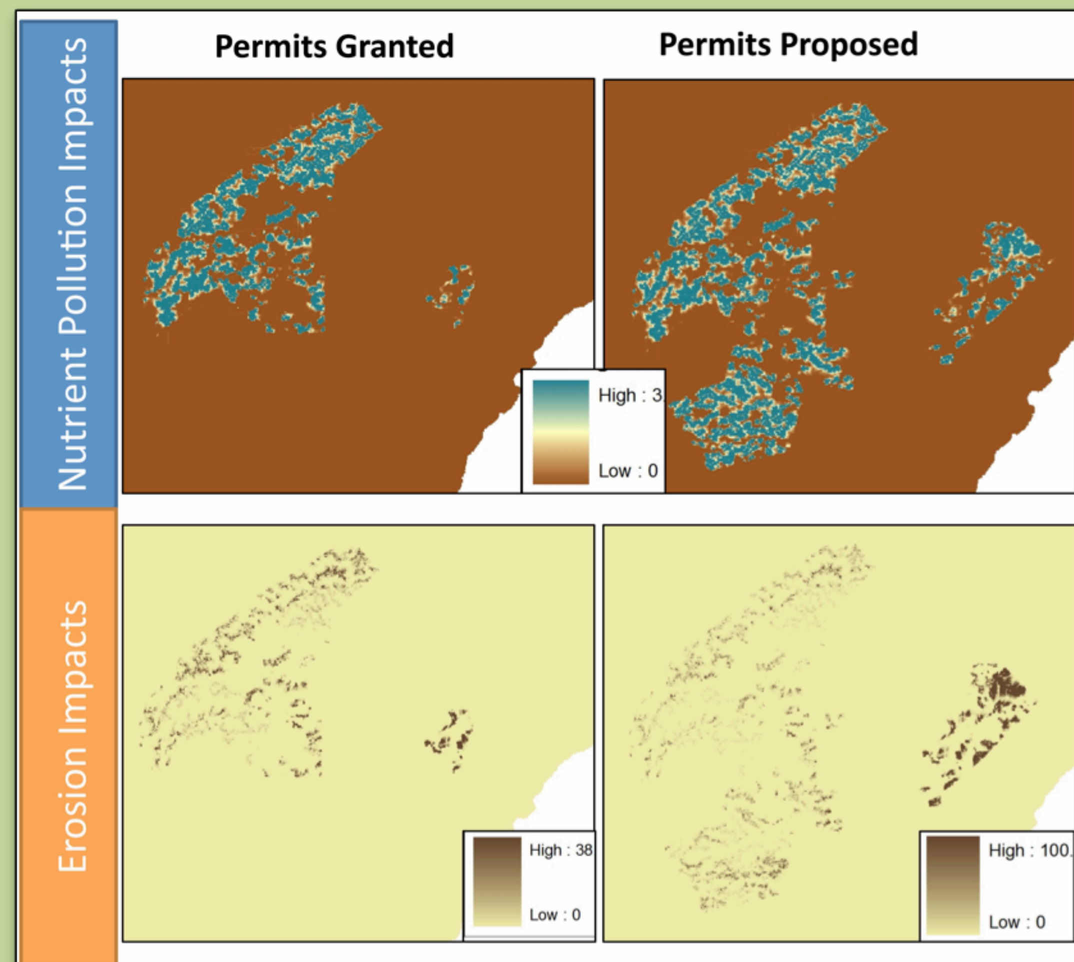


Figure 4. Estimated impacts of full build out of mining permits already granted and of proposed mines on nutrient pollution (total nitrogen; units are kg/ha/yr) and erosion (units are tons/yr). Nutrient pollution impacts occur somewhat evenly across the landscape while erosion impacts are much higher (darker brown) in the eastern mountainous region where conversion to mines will happen on steep slopes and in areas with native forests.

Once impacts are estimated, it is critical to understand to whom impacts will flow. Using the servicesheds identified in Step 1, we summarized the impacts to each beneficiary under each proposed option of mining expansion (Fig. 5). Overall, the people living along the wetland and downstream on the Magdalena River will receive the most impacts since they are downstream of the full set of proposed mines in either option.

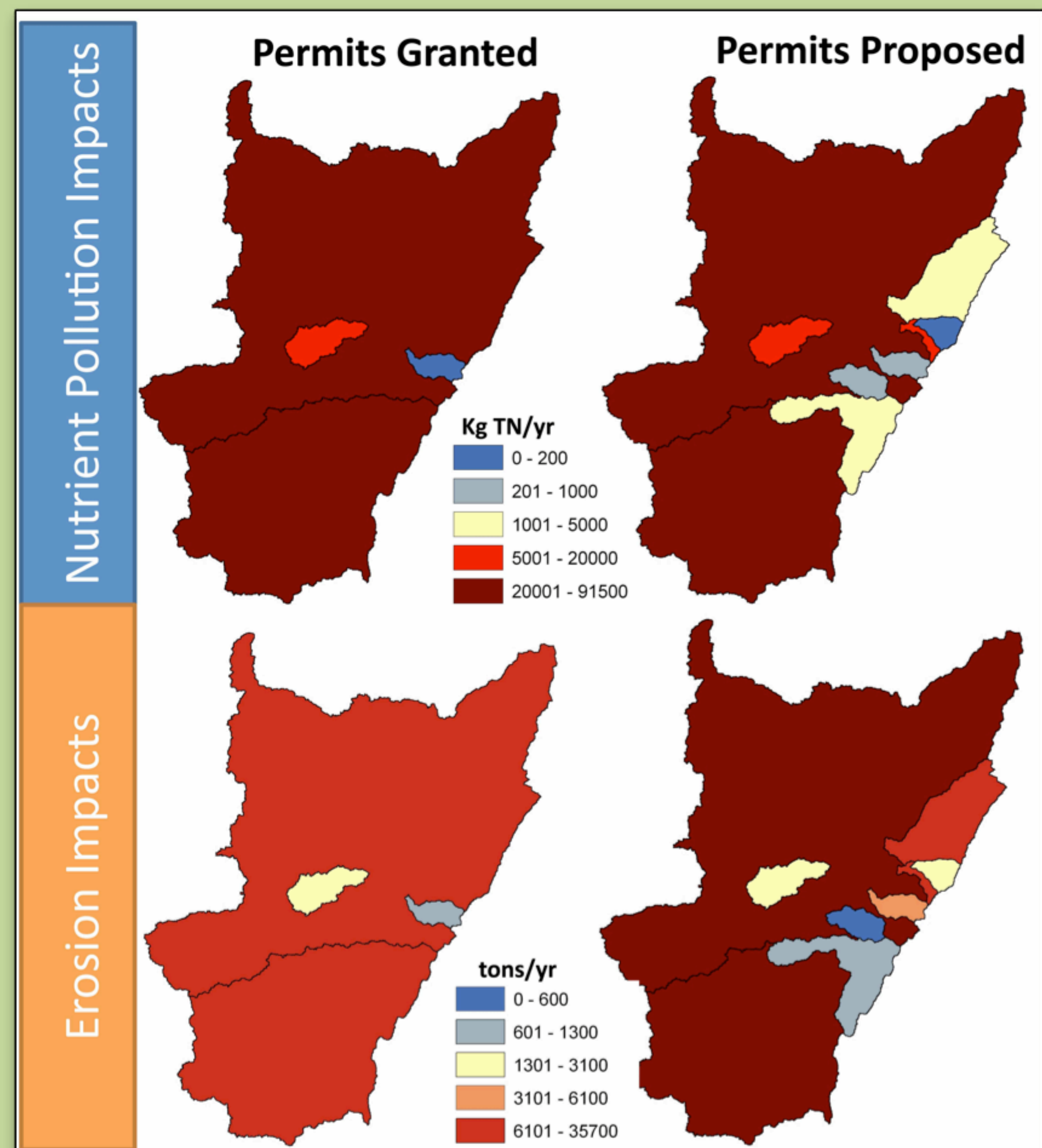


Figure 5. Mining impacts summarized to servicesheds. People living on the wetland (represented by the large serviceshed containing the northern half of the region) and those living on the Magdalena River downstream (represented by the serviceshed containing the entire basin) will receive the highest nutrient pollution and sedimentation (erosion) impacts as the majority of proposed mining activities happen within these servicesheds.

Apply a mitigation ratio

There are several factors that have led to the development of a mitigation ratio in biodiversity offsetting. There is often a time lag between the start of offset activities and the establishment of new fully functional systems which means that biodiversity or ecosystem services are not protected or provided during that lag time. There is some risk associated with restoration activities and it is always possible that restoration activities will fail. In addition, there is variation in the status of biodiversity across regions. Given these factors, a ratio is commonly used to adjust the amount of offset required. In the biodiversity context, offsets are area-based. For example, a 2:1 ratio may be applied in a case where no net loss of wetlands is desired. If 10 hectares of wetland were damaged, 20 hectares must be replaced.

The approach and many of the factors applied in the calculation of biodiversity offset ratios are also relevant to the calculation of ecosystem service offset ratios with two key differences: 1) area-based offsetting is not appropriate and 2) for some services, the lag time factor used in calculating the offset ratio must be applied based on the restored system not the impacted system.

Area-based offsets for ecosystem services are not effective for two reasons. In biodiversity offsetting, the type of habitat impacted is the type of habitat that must be replaced. However, many ecosystem services can be provided, at different levels, by different habitat or ecosystem types. For example, the biodiversity in a tropical grassland converted for a development project can only be replaced by more tropical grassland. But the carbon sequestration lost in the same conversion could be replaced with carbon sequestration by restored humid tropical forest. As such, offsetting should be based on amounts of ecosystem services, not areas of habitat.

It may be tempting to think that other services, especially those associated with specific species or habitat types (such as commercial or recreational fishing or wildlife viewing) could be addressed with an area-based approach. These services behave like biodiversity because the kind of habitat impacted is the same kind that must be replaced to restore the service. However, simple area-based measures would ignore the critical link between people and nature required for ecosystem services to flow. Biodiversity impacts from the loss of a commercial fish species' habitat during development could be offset by restoration of that same habitat anywhere else within the same watershed. However, if the restored area is not accessible to people for fishing, the ecosystem service impacts would not be offset. Because of these complexities, applying the mitigation ratio to ecosystem service estimates, not impacted area, ensures that impacts are appropriately addressed.

As with biodiversity, ratios should be adjusted for the rate of ecosystem service loss, services identified as priorities, rarity of the service, length of time actors are committed to continuing offset activities and the lag time between the start of activities and the full recovery of ecosystem service delivery. The translation of these factors into a mitigation ratio calculation has not yet been done for ecosystem services. We are in the process of developing this approach. Because there is no established approach for ecosystem service mitigation ratio estimation, we used a 1:1 ratio in the Cesar demonstration case. This means that our offset requirements represent the absolute minimum possible requirement for the proposed mining expansions.

Estimate offset potential

Once the mitigation ratio is determined, and the total amount of offset requirement estimated, locations for offsets should be chosen that allow the most efficient and effective options for reaching the required mitigation. Both protection and restoration actions can be considered for mitigation, and the preference for each activity will vary across countries and regions. To ensure that the same benefits are provided to the same people, mitigation must be done within the same serviceshed where the impact occurred. This approach will avoid the unintentional redistribution of services that has resulted from existing mitigation programs such as the Clean Water Act in the United States. Maps of where protection and restoration activities will lead to the biggest ecosystem service improvements will help determine where offsetting will reach target goals most efficiently. These maps will also reveal if there are servicesheds where there is not enough mitigation potential to offset the impacts of proposed development. In such places, people will experience some level of impact regardless of how much mitigation is done. When this happens, there is a 'mitigation debt', or an amount of impact that cannot be offset through protection and restoration on the landscape. The Ministry can choose to avoid granting some of the proposed development in these places to bring development impacts back into balance with mitigation or they may choose to apply alternative mitigation strategies such as technical solutions (water treatment facilities, bottled water delivery, etc) or direct payments to beneficiaries to offset the damages they will experience.

Estimating Offset Potential in the Cesar Department

Colombia does not have a 'no net loss policy' and habitat conversion is still progressing at relatively high rates. Given these conditions, protection is the preferred activity for mitigation offsets. We first developed a scenario that represents how much ecosystem service benefit will arise from protection. Some protection will already happen as offset actions to mitigate for biodiversity impacts (as already required by law) and we want to give credit for those actions. The Ministry has accepted TNC's biodiversity portfolio areas as those that will be targeted for biodiversity mitigation. We asked how much ecosystem service mitigation is possible from protecting the full biodiversity portfolio of sites (Fig. 3). We used the same InVEST models to estimate improvements in nitrogen pollution regulation and erosion control from habitat protection and summarized how much improvement is possible in each serviceshed (Fig. 6).

We then asked if this mitigation potential was enough to offset the likely impacts from each proposed mining scenario. We calculated what we call the 'mitigation balance', the difference between the impact for each mining option and the mitigation potential calculated in this step. This approach highlights which towns have the potential to have the same services delivered post-mine development through mitigation, and which do not (Fig. 6). The town of Potrerillo (population in 2005, 827) will receive unmitigated nitrogen pollution and erosion impacts in both mine expansion scenarios. In addition, protection cannot offset the erosion impacts to La Jagua de Ibirico (pop. 16,694), Becerril (pop. 9570), La Victoria de San Isidro (pop. 1741) and Estados Unidos (pop. 158) if all proposed mines are permitted (Fig. 6).

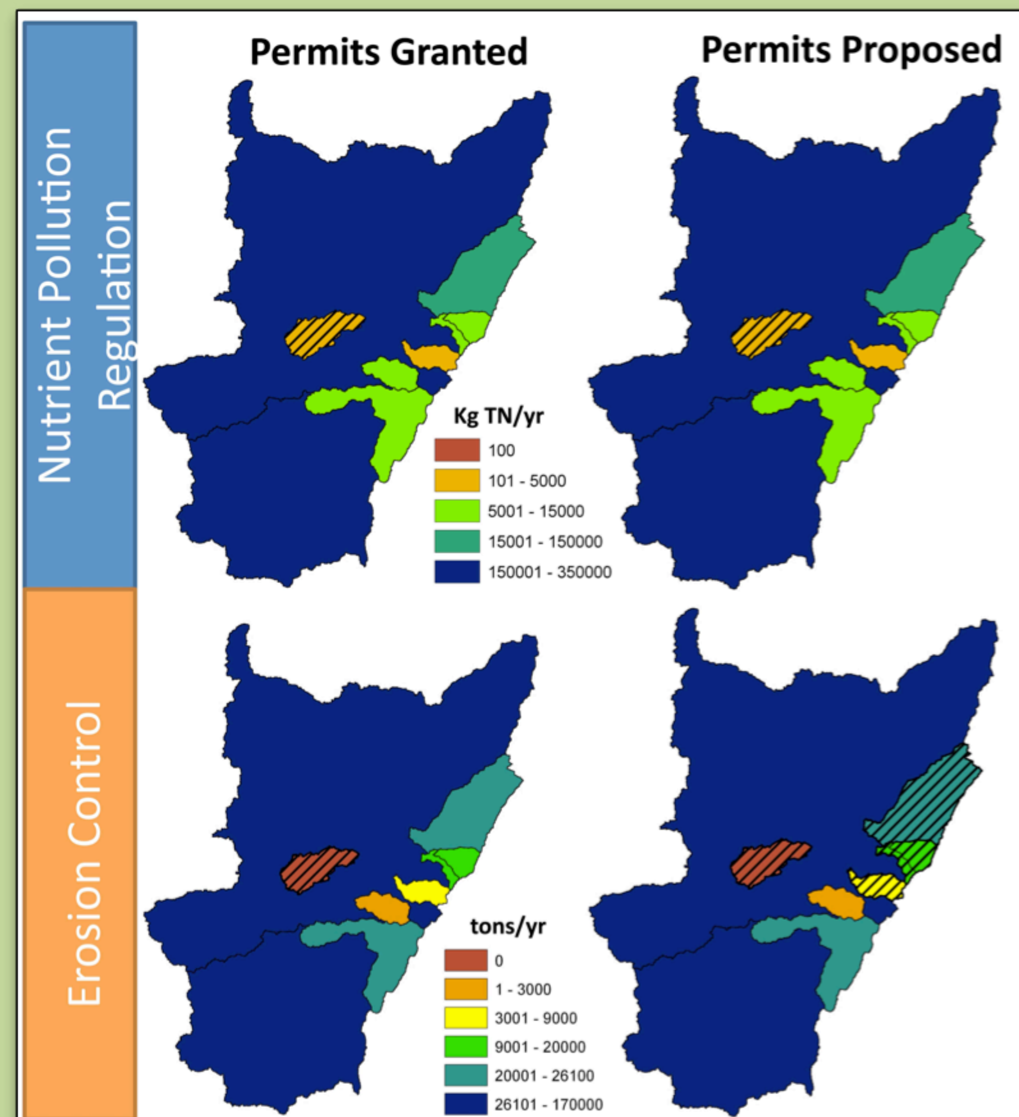


Figure 6. Ecosystem service benefits from protecting the biodiversity portfolio of sites. In hatched servicesheds, the benefits from protection are not big enough to offset the impacts from proposed mining development.

It is also possible to achieve mitigation through restoration activities, so we asked if the sevicesheds with mitigation debts after protection of the biodiversity portfolio could achieve a mitigation balance through restoration. To identify priority areas for restoration on the landscape, we used TNC's priority corridor areas and asked

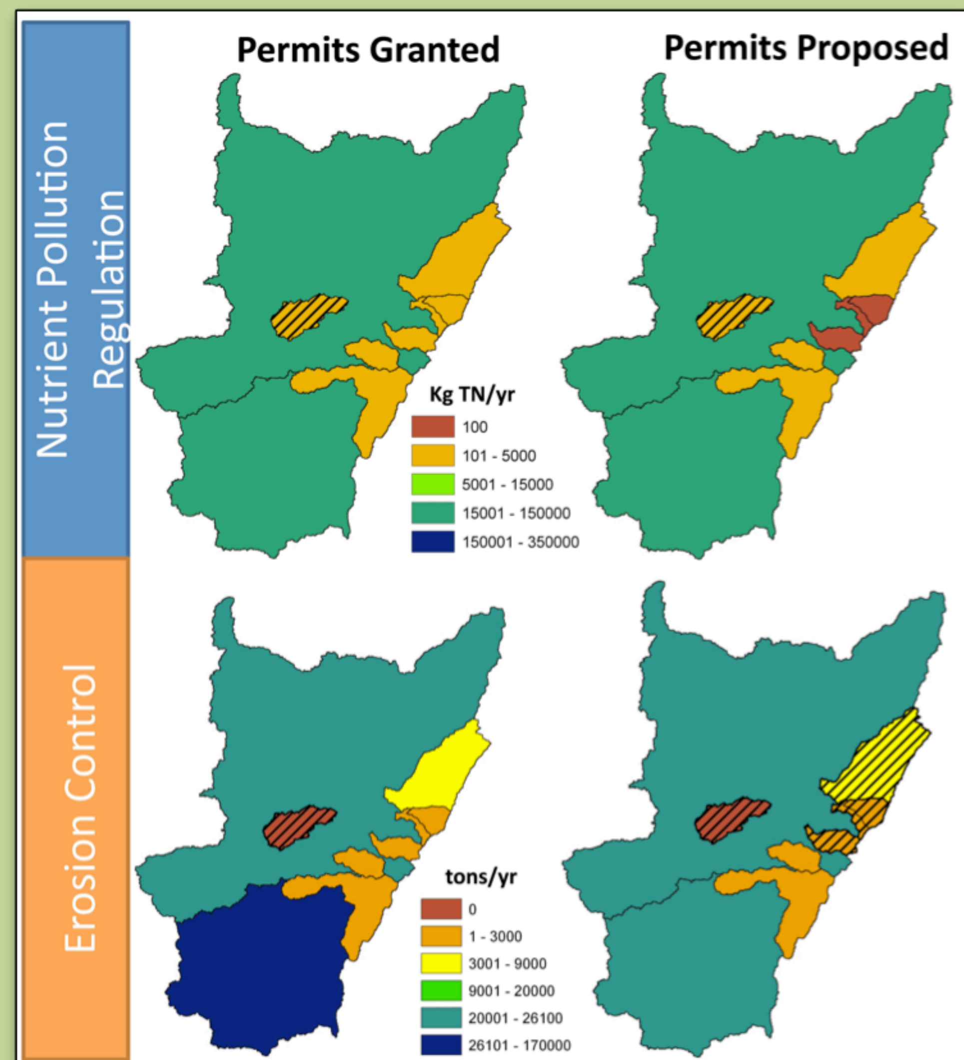


Figure 7. Ecosystem service benefits from restoring corridor areas. In hatched servicesheds, the combined benefits from protection and restoration are not big enough to offset the impacts from proposed mining development. In the cities downstream of these servicesheds, impacts will be experienced if proposed mining is allowed.

how much ecosystem service benefit would result from restoring these areas to natural habitat. We again used the InVEST models and summarized potential benefits to each serviceshed. Although restoration does provide substantial additional benefits (Fig. 7), they are not enough to reach a mitigation balance in any of the servicesheds that had a mitigation debt. These cities would receive lower impacts if both protection and restoration were used, but some impacts would still remain. These analyses show that ignoring ecosystem services in mine permitting would lead to unintended consequences for many cities in the Cesar Department. We also show that mitigation through protection and restoration will not be enough to offset all of the impacts of the mines to all cities. This means the Ministry should consider limiting mine expansion to avoid these impacts, or identify alternative ways to compensate people in cities that will be impacted.

Conclusions

The expanded mitigation hierarchy provides a framework for clearly and consistently addressing the impacts of proposed development projects on ecosystem services, and the potential for mitigating those impacts through protection and restoration. In the Cesar Department case, applying the framework revealed that all feasible landscape-based mitigation is unlikely to compensate for all ecosystem service impacts within some servicesheds, suggesting that regulations will need to be more prohibitive if negative effects are to be avoided. The framework provides the option of identifying who will lose services. For example, the residents of Potrerillo will receive unmitigated impacts on both erosion and water pollution under all options presented for mine expansion and an additional ~28,000 people will receive erosion impacts from development of all proposed permits. The Ministry can use this kind of information to avoid unintended social impacts of granting mining permits. If mitigation cannot return the same benefits to the same people, the Ministry could choose to avoid granting permits in that area, or take other actions to compensate residents for their losses. In either case, unintended consequences, such as those resulting from the current approach to wetland mitigation banking in the United States and other countries, can be avoided. This approach will provide the Ministry with the greatest benefits if multiple ecosystem services are assessed and results are combined with information on priority areas for biodiversity protection and on likely revenues from allowed permits. Combining all three pieces of information will allow the Ministry to meet the goals of biodiversity conservation, development and human well-being most efficiently.

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