Economic-Ecological Evaluation of Dynamic Offset Contracting in Alberta's Boreal Forest

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Abstract

We examine the economic and ecological tradeoffs associated with trading temporary offset contracts to manage the impacts of development in Alberta's boreal forest. Principles for biodiversity offsets emphasize securement of long term ecological benefits, with many programs requiring a deed restricting mechanism such as an easement before offset credits can be transferred. This creates challenges for implementing offsets on public lands where there is no mechanism for private agents to secure land for long term conservation benefits. Furthermore, permanent offsets may be at odds with the ecological and human dynamics of working landscapes. We consider a number of offset policy choices including: reclamation versus avoided loss as eligible actions; time lags for certification of offset credits; and definition of offset service areas. We find that offset programs in which reclamation is the only eligible activity for creating credits may be cost prohibitive in relatively intact landscapes which will be subject to intensive future development. Programs which credit avoided disturbance through project delay are cheaper by orders of magnitude however the accounted for net gain in conservation is lower because of leakage. On the other hand, conserved habitat can reduce ecological risk, particularly at early stages of development in a region when there may be ecological bottlenecks as restored landscapes catch up. The results have implications for offset design, particularly the role of permanent versus temporary offsetting, accounting for time lags and uncertainty, and criteria for additionality.

Introduction

Canada’s boreal forest is one of the world’s most important ecosystems. Covering 58 per cent of the country, it is still largely intact and comprises 25 per cent of the world’s remaining original forest (Boreal Leadership Council 2013). It is home to a rich array of wildlife including migratory birds, bears, wolves and caribou, all of which are at risk from increasing industrial pressure from increasing world demands for timber and mineral resources (Dyer et al. 2008; Boreal Leadership Council 2013, Mahon et al. 2014). In particular in Alberta area the boreal contains some of the world’s richest conventional and unconventional oil and gas deposits including oilsands where production is expected to increase from its current level of about 2 million barrels per day to 5.2 million barrels a day by 2030 (Canadian Association of Petroleum Producers, 2013). The question in how this scale of development can be managed to ensure long term ecological integrity and protection of ecological values.

Canada’s forests are mostly public land. Development is administered by provincial governments through an assortment of dispositions for oil, gas, and timber rights Most land is covered in multiple dispositions, and sectors must manageresource access on a land base that is increasingly restricted due to environmental concerns including impacts to species at risk such as caribou. Requirements for ecological management of public forest land are delegated to forest companies who are required toengage with stakeholders and the public to develop long term forest management plans which account for multiple social and ecological values. These plans are often in conflict with the dynamics of exploration and development of oil and gas deposits which are driven by underlying geology, and world energy prices. The seemingly unplanned and uncoordinated development of oil and gas reserves wreaks havoc on forest management plans, interfering with harvest schedules and ecological objectives such as habitat protection.

While much international attention has been devoted to the impacts of oil sands mining, the main future impacts from oil sands development will come from in-situ projects which will affect a much larger area through fragmentation from the development of roads, seismic lines, well pads, pipelines and processing facilities. While the impacts of a single energy project may not have significant ecological impacts, the cumulative effects are substantial. Estimates of land use intensity for in-situ development ranges from 1.4 – 1.8 hectares per million barrels of oil (Grant et al. 2013; Schneider and Dyer 2006), with disturbance from energy development outstripping disturbance from forest harvesting in Alberta (Dyer et al. 2008). Although this footprint must be reclaimed the lifespan of in-situ projects ranges from 20-60 years (e.g. Schneider and Dyer 2006; Grant et al. 2013). These are semi-permanent impacts which on the long side of the life span are comparable to the age of rotation for hardwood stands which is 60-80 years.. Thus, even with stringent reclamation requirements, without additional policies to support ecological values on the working landscape there will be significant risks and adverse effects for habitat and species over the next 10 to 50 years (Environment Canada 2011; Mahon et al. 2014).
Conservation offsets are compensatory actions to address the ecological losses arising from development and if properly designed can be used to coordinate the collective impacts of development to meet landscape or regional ecological objectives. Over the last decade there has been increased attention in Alberta on establishing a regulatory offsets program for oil sands development (Dyer et al. 2008; Croft et al. 2011; Alberta Conservation Offsets Advisory Group, 2010). A number of companies already use offsets on a voluntary if ad-hoc basis. Federally, the Government of Canada has also been applying offsets through Environment Canada's and Department of Fisheries and Oceans' environmental review and approval processes (Environment Canada 2012; Department of Fisheries and Oceans 1985).

In 2008, Alberta developed a new land use policy to address cumulative effects. The 2008 Land-use Framework calls for the development of regional plans with objectives and thresholds for land, air, and water outcomes, and identifies offsets as an option for meeting these objectives (Government of Alberta 2008). The completed Regional Plan for the Lower Athabasca in Northern Alberta proposes to manage cumulative effects through integrated land management; timely and progressive (accelerated) reclamation of disturbed lands; and limits to land disturbance. In December 2009, enabling legislation for offsets was passed under the Alberta Land Stewardship Act however an offset program has not yet been established. As a result offsets are being used on an ad hoc basis, but there is no standardized approach or consistency to ensure that ecological objectives are being achieved.

The Business and Biodiversity Offset Program (BBOP) has developed a standard on biodiversity offsets that is gaining wide acceptance (BBOP 2012). The standard requires adherence to a number of principles that in theory should lead to no net loss of biodiversity. These include adherence to the mitigation hierarchy (avoid, minimize, compensate); ensuring that compensation actions are "additional" and result in real biodiversity gains; and that biodiversity benefits are long term preferably through permanent securement.. This standard is similar to requirements for wetland and habitat banking under the United States Clean Water Act, and the United States Endangered Species Act. In particular, the Acts require adherence to the mitigation hierarchy, and ecological benefits must be secured in perpetuity through an easement. Offset programs in Australia, South Africa, and Europe follow similar principles, emphasizing no net loss, additionality, and long term securement of ecological benefits. The BBOP standards have been developed for localized and spatially limited projects like mining, and building and infrastructure (e.g. Gardner et al. 2013). With a regulatory focus in Alberta on regional cumulative effects the context under which offsets are being considered is more complex, requiring approaches that address multiple small projects that have limited impacts on their own, but for which the cumulative impacts over a region are expected to be high.

In practice there are numerous challenges to achieving no net loss and there is considerable debate as to whether offset programs are achieving this objective (e.g. Gibbons & Lindenmayer 2007; Clare et al. 2011; Curan et al. forthcoming). Additionality is required to ensure measurable gains from offsets and NNL. Baselines for measuring net benefit can either be the current state, or a counterfactual future business as usual trajectory under no offsets. Most offset programs are based on habitat restoration in order to ensure that conservation funds are not used to purchase 'paper parks' in areas that were not actually threatened by development (Quetier et al. 2014). This creates a perverse administrative preference for ecological restoration over habitat retention even though maintaining existing habitat is critical to ecological health and reducing environmental risk, especially in the short run where there is the potential for ecological bottlenecks to arise due to long timelags and uncertainties in achieving restoration benefits (Bekessy et al. 2010; Maron et al. 2012; Curran et al. forthcoming). Furthermore, a lack of restoration opportunities can be a challenge in landscapes such as Alberta's boreal, which are relatively undisturbed but are poised to undergo future intensive development.

Bull et al. (2014) show that the choice of baseline determines whether an offset scheme achieves NNL. With a current state baseline, for example, offsets are more likely to achieve NNL when biodiversity is increasing; on the other hand using a counterfactual baseline achieved NNL when biodiversity was declining. These findings highlight an important source of confusion between the design of the policy instrument and the policy goal (e.g. Ferraro and Pattanayak 2006). In particular, NNL is an offset design principle which does not necessarily align with policy goals. Ideally offset design should be guided by policy targets for the protection of biodiversity (Brownlie and Botha, 2009; Pilgrim et al. 2013). When society is prepared to accept losses, these can be limited by purchase and/or protection of areas of similar biodiversity value, for example through conservation banking and biobanking (e.g. Fox and Nino-Murcia, 2005; Department of Environment and Climate Change, New South Wales). Offsetting then sets an upper limit on habitat losses in a region, highlighting the constraint of land availability for achieving both development and nature conservation goals (Quétier and Lavorel 2011; 2014).

Another difficult challenge is ensuring lasting benefits. Until recently it was assumed that permanence was required to achieve additional lasting conservation gains. This approach views offsets as permanent protected areas on private lands, complementing parks and other permanent ecological reserve designations. However there is often landowner resistance to permanent agreements making them costly and more difficult to site, and deed restricting mechanisms such as easements can be difficult to enforce. On public lands, there are no mechanisms to permanently set aside land, except through creation of protected areas, in which case governments could create the parks to begin with. Another way to think of offsets is as temporary mobile conservation and recovery features that are used on 'working landscapes' to complement protected area strategies and reflect habitat needs during vulnerable periods of species' life cycles which are continually changing due to shifting social and economic values that affect land use over time. There is increasing evidence that lasting ecological benefits may not only be derived from, but be dependent on mobile dynamic approaches to offsetting (Bull et al. 2013). Dynamic offsetting could be achieved through a broader suite of conservation agreements of different long terms and shorter term duration with the goal that they collectively at any given point in time meet conservation objectives.

In this study we examine options for using offsets to manage for biodiversity outcomes in Alberta's boreal forest. To address the challenge of implementing offsets on public lands where there is no mechanism for agents to secure land in perpetuity we consider the trading of temporary offset credits which can be generated from either the delay of an activity or project (conservation), or reclamation of disturbed forest. Temporary offsets have been explored extensively for forest carbon, and options that work for forest carbon can be applied to conservation offsets (e.g. Sedjo and Marland 2003). Under our policy temporary offsets would be required until land is certified as reclaimed at which point the offset contract could be re-sold or terminated. Key features offset design that we consider include use of a generalized biodiversity intactness metric to assess ecological gains and losses; impacts of changes in eligibility rules for reclamation versus conservation activities; and the time lag for certification of offset benefits.

This study builds on a number of previous studies that have examined ecological and economic tradeoffs of conservation strategies in Alberta's boreal forest. The economic analysis is based on Hauer et al. (2010) which develops an integrated economic – ecological spatially explicit dynamic optimization model to explore inexpensive options to maintain target species within their historic range of natural variation. Schneider et al. (2010) show how triage through spatial targeting of limited conservation budgets may reduce the vulnerability of caribou though not the vulnerability of specific herds. Schneider et al. (2011) use Marxan conservation planning software (Watts et al. 2009) to generate reserve designs for the boreal that optimize resources. Similarly Habib et al. (2013) find significant cost savings from offset programs that use a flexible biodiversity intactness index to measure ecological gains and losses relative to programs that require strict equivalence based on vegetation type. An important aspect of their policy is that Marxan is used to optimize the location of offsets within regional conservation priorities, which is consistent with a policy where government collects development charges and then spends the fees on protection.

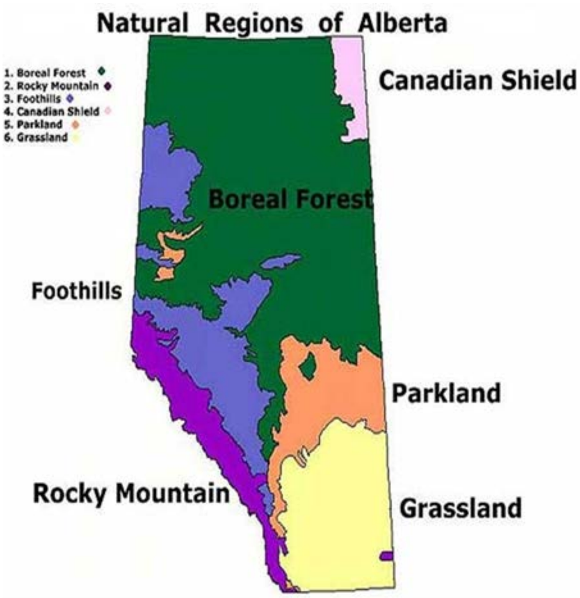
An important difference between this analysis and the previous studies is that the latter look at tradeoffs from a planner's perspective where outcomes are optimized over the landscape. However, offset programs generally involve transactions between autonomous buyers and sellers, and significant administrative costs could be imposed by targeting offsets towards priority areas if new governance structures are required to administer funds. In addition, exploration and development activity solves a dynamic information problem for government about the value of underlying reserves and the opportunity costs associated with specific sites. Without this information problem there is no real justification for government to allocate leases in the first place if they are just going to require public land to be set aside somewhere else. Finally interactions between development and biodiversity are non-linear and hence optimal solutions are path dependent. Therefore it is not clear that the optimal outcomes outlined in previous papers are actually feasible.

Our evaluation takes a different approach and considers a decentralized offset program, where companies trade impacts autonomously based on cost, trading rules, and equivalence requirements. We are interested in how costs and benefits vary as we change design elements. While the approach of Habib et al. (2013) is inherently static, we explicitly consider the evolution of activity and protection on the landscape as reserves are exploited, and the impacts on biodiversity over time. By considering conservation contracting rather than permanent offsets, we introduce flexibility over time as well as space.

The Study Area

The Study Area is comprised of Alberta's boreal forest which covers approximately 465,000 km2, or about 8 per cent of Canada's boreal forest area (see Figure 1). The region includes three major watersheds, the Athabasca, the Peace, and the North Saskatchewan, which are the basis for Alberta's planning region boundaries. There are five planning regions which have all or part of their area in the boreal: Lower Peace, Upper Peace, Lower Athabasca, Upper Athabasca, and North Saskatchewan.

Figure 1 Map of Alberta's Natural Regions



The boreal ecosystem has been classified into a number of vegetatively distinct natural sub-regions based on soil type, topography, and disturbance history which are influential in determining the composition of species at a sub-regional scale (Alberta Sustainable Resource Development 2005). For example the Dry Mixedwood is characterized by aspen-dominated forests and fens while the Central Mixedwood, the largest subregion, is characterized by upland forests and wetlands. The Athabasca Plain has sand dunes and jack pine communities and the Peace Delta has sedge meadows and marshes. The Northern Mixedwood and Boreal Subarctic subregions contain black spruce bogs and fens, with significant areas of permafrost (Alberta Ministry of Tourism, Parks and Recreation 2006).

The Model

Land is allocated under timber and energy dispositions. To simplify the analysis, we assume that both sectors are required to offset their impacts. Note that this is inconsistent with existing rights for forest companies, as their disposition is for the harvest of trees. However this allows us to abstract from the underlying property rights in order to better understand opportunities for trade and the economic burden of alternative policies which is independent of the initial distribution of rights (e.g. Montgomery 1972). All industrial activities are assumed to be temporary, although they may occur over several years. The duration of the offset obligation is also temporary, until an area is reclaimed and a reclamation certificate is issued.

At any point in time a disposition holder may either be a developer or an offset provider. In deciding whether or not to buy or sell offsets a company compares the net present value of the project at the particular site and point in time (e.g. developing a well, or harvesting a cut-block) with the price of an offset. If the value of an offset is higher than the value of the development, development will be delayed and instead the company will create an offset and sell the credit to another developer. If the offset price is lower than the project value, the project will go forward and an offset will be purchased. Developers of high valued sites have a high willingness to pay for off-sets and will be buyers. Conversely, developers with marginal development sites have a low a low willingness to pay for offsets and will become sellers. By calculating the net present values of schedules of activities at different locations we can evaluate individual decisions in any period, and then aggregate these in order to derive demand and supply curves for offsets.

The economic cost of an offset policy is the opportunity cost associated with foregone revenues resulting from the delay or cancelation of projects as well as the cost associated with advancing the timeline for reclamation. It is important to distinguish economic costs, which are based on opportunity cost, from business costs. For example, a lessee that cancels or delays a project in order to sell an offset is not worse off from the transaction since the cost is recovered or compensated by payments from another developer. However, this transaction results in a cost to society which loses the value of the development. The economic burden of the loss falls on the developer that pays for the offset. The opportunity costs are offset by the social benefits of conservation. Determining the optimal balance between conservation and development is beyond the scope of this study. Instead we are interested in the most efficient way to achieve the environmental objective which we assume is to maintain biodiversity.

Net present values were developed using TARDIS, a dynamic spatially explicit optimization model for forestry and energy activities (Hauer et al. 2010). TARDIS optimally schedules forestry and energy activities over 50 years by Alberta Township System sections based on maximization of net present value (Alberta Geological Survey 2009). The model generated optimized activity schedules and land values at a section level for each of the following sectors: forestry, conventional oil and gas, and in-situ bitumen extraction. This information is used to generate the demand and supply curve for offset contracts.

Equivalency is central to the concept of offsets and is based on criteria such as site quality, similarity of species supported by a site, ecological risks, and proximity to communities. Equivalence is based on the metrics chosen to measure ecological losses and gains at a particular site, as well as offset rules which are policies that are designed so that offset programs meet specific social and ecological objectives. These include no-net loss rules; regional trading constraints; and mitigation ratios to address risk or to target development and offset activities into specific areas. In discussing equivalence it is important to maintain the distinction between offset metrics and rules. Offset metrics measure and differentiate the ecological values that are gained and lost in offset trades, while rules define the substitutability between ecological values at different times and locations.

In this study, the metric used to measure ecological losses and gains is an index of biodiversity intactness developed by the Alberta Biodiversity Monitoring Institute (Alberta Biodiversity Monitoring Institute 2011). Biodiversity intactness indices were calculated for Alberta Township System sections. Land disturbance affects species in a variety of ways ranging from habitat loss and fragmentation to more subtle changes in habitat quality. The intactness index integrates the responses of different species that are both positively and negatively affected by disturbance and represents an assessment of the condition of biodiversity. The value of the index ranges from 0-100, with 100 representing biodiversity in the absence of any land use disturbance. Biodiversity intactness is predicted as a function of the percentage of successional and alienating disturbance in a geographic unit, as well as the percentage of lowland and geographic location. Successional disturbances are those that grow back to some form of native vegetation and include cut- blocks, seismic lines, power lines, and pastures. Alienating disturbances are those that permanently disturb the soil and eliminate or replace vegetation and include cultivated crops, roads, urban, well pads, industrial sites. The intactness index shows changes in ecological condition from site improvements or degradation, and can be applied to any site no matter what stage of development it is in.

Using intactness to measure losses and gains is similar to the quality adjusted habitat hectare approaches that have been used in other programs (Parkes et al. 2003). This implies that two hectares of habitat of 50% quality can offset one hectare of pristine habitat (100%). The intactness index acts as a mitigation ratio for trading equivalent areas of different quality; that is 50% and pristine habitat are substitutable at a 2-1 ratio. Ideally, an offset site should have similar attributes as an impact site in terms of the species, communities, and ecosystems affected, however matching losses and gains based on similarity can be very complex, and reduce trading options for large scale programs (e.g. Nemes et al. 2008). Instead many offset programs rely on geographic proxies such as distance or ecological zoning to define offset service areas in order to account for issues such as proximity between losses and gains, and similarity between habitat and ecosystem types. Offset trading is then constrained or prioritized to fall within the bounds of these service areas.

The schedules and net present values generated by TARDIS were exported into an EXCEL spreadsheet model where supply and demand curves for offsets under different offset policies were generated by ranking eligible sites by net present value or ‘cost’ per offset unit weighted by each site’s intactness score. The EXCEL model is a linear program that optimally reschedules forestry and energy sector activities subject to offset requirements which require that the loss of intactness at a development site is replaced with a gain in intactness somewhere else. There are 6 five year periods in the offset market model, covering 30 years. The variables in the model are development projects and offsets which take place on a section level. The model optimizes sections of forestry harvest, sections of energy development, sections of conservation offsets and sections of reclamation offsets. Conservation offsets are sites that can’t be developed in a given time period however they can be developed in the future. Conservation offsets do not improve the ecological quality of a site however they count as a gain if the site would otherwise have been developed.

The results show the economic cost of an offset program in terms of the net present value as well as the trajectory of land use for each section of land and whether it is under development, conservation, or reclamation in any period. The site level intactness measures are aggregated in order to determine whether the average quality of sites is increasing or decreasing over time. It is important to note that this is not equivalent to evaluating regional intactness, which would be based on an evaluation of intactness (0-100) at a regional scale. Thus although the measures are correlated we can’t draw conclusions about the change in site condition on regional biodiversity intactness.

We evaluate a number of offset policies consisting of different combinations of eligibility rules and service area constraints. A summary of the scenarios modeled is outlined in Figure 2 below. First we look at the impact of eligibility rules when equivalence is defined only by changes in intactness with no other constraints. We considered two different eligibility rules for creating offsets: reclamation and conservation (avoided loss). We also consider the impact of 5 year versus 20 year time lags for certification of reclamation credits. This leads to four policy scenarios highlighted in the first column of Table 3: conservation offsets; reclamation offsets only with a 5 year certification period for offset credits; conservation and reclamation offsets together with a 5 year certification period; and finally conservation and reclamation offsets with a 20 year certification period. We then consider a second set of scenarios related to constraints on the offset service area. These are evaluated for the case where both conservation and reclamation offsets are allowed with a 5 year certification period for reclamation credits. These scenarios are depicted across the columns of Figure 2. The first scenario allows trading across the boreal with no restrictions. A second scenario restricts the service area to Alberta's regional planning boundaries. A third scenario considers service areas defined by Alberta's natural sub-regions, and a fourth combines both grizzly habitat and natural sub-regions into service areas. All of the scenarios are all compared to an unconstrained base run with no offset requirements.

Figure 2 Modeled Offset Policy Scenarios

Base Case – No Offsets	Offset Metrics and Trading Rules			
	Metric	Service Area Constraints		
Eligibile Actions and Certification Period	Biodiversity Intactness	Alberta's Land Use Planning Regions	Alberta's Natural Subregions	Alberta's Natural Subregions and Grizzly Habitat
Conserve Only	x			
Reclaim Only (5 yr lag)	x			
Conserve and Reclaim (5 year lag)	x	x	x	x
Conserve and Reclaim (20 year lag)	x			

For the remainder of the paper Scenario Set 1 will refer to the first set of scenarios related to eligibility rules outlined in column 1 of Figure 1. Scenario set 2 will refer to different service area scenarios outlined in row 3 of Figure 1.

Results

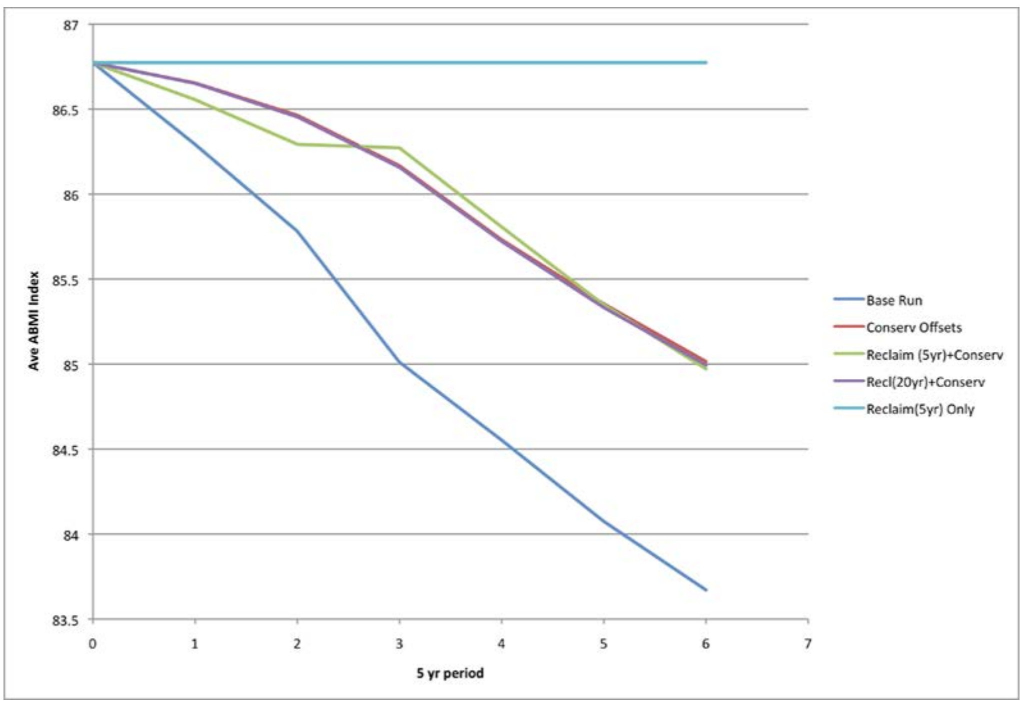
The costs for Scenario Set 1 are shown in Table 1 below. The objective function values are discounted profits minus discounted reclamation costs. The value of the objective function was $299,438 million dollars in discounted profits for the base run scenario. This represents the maximum unconstrained value of development. The column labeled "Difference from Base" is the difference between the objective function value of the model run and the objective function value for the base run. This difference represents the opportunity cost of implementing the offset system in terms of forgone profits and the costs of putting resources into reclamation. By far the system with the greatest opportunity cost of 115 billion is the offset system that permits reclamation only, with a 5 year lag on certification of benefits. This represents a decrease of 38.4% decrease in the discounted value of revenue relative to the base case. When conservation offsets from avoided disturbance are introduced into the system the costs drop to less than 1.5% of potential revenue, or approximately 0.5 to 4.5 billion dollars (see the last three rows of Table 4). Increasing the lag time for accreditation of offset benefits from 5 years to 20 years increases costs by $4 billion. It is important to note that these costs are borne over 30 years of the modeling run, so the annual costs are very low (as low as $500 million over 30 years).

Table 1 Net Present Values of Profits for Scenario Set 1 (CAD $Million)

Scenario	Objective Function	Difference from Base	% Difference from Base
Base case	$299,438.3	NA	NA
Conservation only	$294,913.9	$4,524	-1.5%
Reclamation only (5 yr. certification)	$184,409.8	$115,029	-38.4%
Conservation and reclamation (5 yr. certification)	$2,989,305.4	$508	-0.2%
Conservation and Reclamation (20 yr. certification)	$294,908.1	$4,530	-1.5%

The ecological gains and losses for Scenario Set 1 are shown in Figure 3. For the base run, the average intactness index drops from 86.7 to 83.6 over 30 years. For the reclamation only run, with a 5 year time lag for certification of reclamation credits no credit for conservation, the average intactness index remains constant over time, which is as it should be given that the market clearing equation requires no net loss and that decreases in intactness from development must be offset by increases from reclamation. Note that this is an accounting outcome because we assume that ecological benefits are established after 5 years. While useful for policy comparison actual ecological losses will likely be substantially greater over the short run. The average intactness index for the other three scenarios which include conservation offsets all shows a decline in average intactness index over time. This represents leakage; companies are getting credit for project delay and avoided disturbance for areas that would not have been developed in any case. These credits are not counted in policies which only allow credits for reclamation. In spite of leakage conservation offsets lead to higher average levels of ecological intactness than the base case. The difference between the economic costs and ecological benefits of the offset program when conservation offsets are allowed represents an important policy tradeoff.

Figure 3 Changes in Biodiversity Intactness under Alternative Policies



While it may seem that the addition of conservation offsets is the overriding factor that deter- mines whether opportunity costs are low or high, it is really a function of the time lag between when reclamation activity occurs and the time when ecological benefits are certified. In the reclamation only scenario, there is no way to maintain no net loss in the level of intactness indicator in the first period of the model because of the 5 year certification lag which does not make offsets available until period 2. The only option is to stop development until offset credits are banked, which leads to the sharp decrease in net present value. The addition of the conservation offsets allows the companies to buy time before reclamation produces the desired results and credits are banked. This is why the opportunity cost for the conservation offset scenarios is much lower. The farther in the future that the reclamation credit is certified, the more costly the offset system; however most of the costs are borne in the initial periods of the offset program because of discounting. As a result it makes hardly any difference whether certification happens in period 5 or period 20.

The second scenario set examines whether service area restrictions significantly affect program costs. The results are illustrated in Table 2 below.

Table 2 shows that imposing regional or ecological constraints on offset service areas has only a very small impact on offset program costs. For example, restricting trades to land use planning regions adds an additional cost of only $27million over 30 years. Restricting the offset trades to the smaller natural sub-regions does increase the cost but only slightly. The cost compared to the base run is still less than 0.5 per cent. Adding a restriction for Grizzly habitat increases cost again but the incremental increase is even less than for natural sub-regions.

Table 2 Offset Costs for Scenario Set 2

Scenario	Objective Function	Difference from Base	% Difference from Base
Base case	$299,438.3	NA	NA
Conservation only	$294,913.9	$4,524	-1.5%
Reclamation only (5 yr. certification)	$184,409.8	$115,029	-38.4%
Conservation and reclamation (5 yr. certification)	$2,989,305.4	$508	-0.2%
Conservation and Reclamation (20 yr. certification)	$294,908.1	$4,530	-1.5%

Regional Distribution of Offset Costs and Benefits

The results presented above can be disaggregated in order to look at the regional implications of offset rules. There are five land use planning regions in Alberta's boreal forest: the Lower Athabasca, Lower Peace, Upper Athabasca, Upper Peace, and the North Saskatchewan. Note that development in the North Saskatchewan is restricted to only public land boreal forest area and thus the values are low relative to the other regions. We examine four scenarios. Three are "global" in the sense that there are no geographic constraints on where offsets may be located. These three scenarios are conservation offsets only, reclamation offsets (5 year lag) only, and conservation offsets and reclamation offsets (5 year lag) combined. The fourth scenario, which is based on combined conservation and reclamation offsets, constrains offsets to be located in the same planning region as the development. We look at the impact of each of the policies on the distribution of development, conservation, and reclamation activities across regions. Table 3 shows the change in development values for each of the planning regions while Table 4 shows the net gain or loss in the aggregate level of intactness of all sites by region.

High value development opportunities in the Lower Athabasca are offset by reclamation and delays in development in the Lower Peace Region. The Lower Peace bears the highest burden of cost in terms of reduction in development opportunity and thus ecologically subsidizes the activities in other regions.

Table 3 Percent Change in Net Present Value (NPV) by Region and Policy (% NPV)

Region	Base Case NPV ($ Million)	Conserve Only	Reclaim Only (5yr)	Conserve and Reclaim (5 yr.)	Regional Service Areas
Lower Athabasca	$183,321,289	0.81%	35.85%	0.03%	0.04%
Lower Peace	$41,795,810	6.14%	63.47%	0.78%	0.49%
North Saskatchewan	$19,150	3.33%	14.35%	0.08%	0.49%
Upper Athabasca	$33,924,308	0.77%	32.57%	0.22%	0.40%
Upper Peace	$40,377,781	0.52%	29.05%	0.14%	0.28%
Total	$299,438,338	1.51%	38.41%	0.17%	0.18%

Table 4 shows the change in ecological outcome as measured by the net change aggregate intactness by region relative to the base case. The Lower Peace and the Upper Peace have the fewest opportunities for conservation while the Lower Peace has the greatest opportunity for reclamation. Under a conserve only policy, intactness units are created primarily in Upper Athabasca which the highest ecological gain under a conservation offset policy. Imposing the planning region constraint greatly changes the distribution of costs and ecological benefits. Without regional trade boundaries, reclamation activity is being substituted away from the other regions towards the Lower Peace. When regional constraints are in place

Table 4 Ecological Trade Balance by Region (Change in Aggregate Intactness)

Region	Conserve Only	Reclaim Only (5yr)	Conserve and Reclaim (5 yr.)	Regional Service Areas
Lower Athabasca	17,082	-13,852	10,634	0
Lower Peace	5,049	47,578	4,827	0
North Saskatchewan	213	-62	190	1
Upper Athabasca	54,771	-16,288	46,182	62,011
Upper Peace	-15,430	-17,378	-16,257	4,245

Table 4 shows the ecological trade balance by region which was computed by subtracting the amount of intactness lost from development from the gains obtained from offsets. Under the reclamation only scenario, the trade balance is constrained to be zero across all of the regions. Note that ecological integrity is reduced in the Lower Athabasca, Upper Peace and Upper Athabasca. The offsets from development activities in these regions are transferred to reclamation activities in the Lower Peace region. Interestingly, when the offsets are constrained to be within planning regions, the Lower Athabasca and Lower Peace have a zero balance, showing that in this case, ecological condition is unchanged. However ecological condition increases in the Upper Athabasca and Upper Peace, suggesting that in these regions there are a large number of areas that will never get developed that are counted as offsets. In the conservation offset only and combined conservation/reclamation scenarios all regions produce a surplus of offsets except the Upper Peace, which has the highest development values and which must purchase offsets from the other regions.

Conclusions

In this paper we conceive of offsets as compensatory strategies designed to achieve an overall regional goal of maintaining ecological condition. The results show that offset program design elements can have a significant impact on the costs and benefits of alternative offset policies, and on their distributional impacts. Additionality and permanence are important features of most offset protocols however this is problematic for public forest lands, where intact land is either unallocated by the Crown, or is in a disposition which requires development. We show that trading temporary offset credits can maintain ecological condition over time while development takes place. In this analysis offsets provide improved ecological outcomes on working landscapes and complement a permanent protected area strategy. Ideally in a public land context the design of reserves and parks should be considered jointly with an offset program to maximize ecological benefits. We also show how different regions subsidize development under different designs. The costs and distributional impacts are important to understanding the ability to achieve individual regional planning goals as well as the political acceptability of different offset policies.

Eligibility rules related to reclamation versus avoided disturbance have the largest impact on policy costs and ecological outcomes. An offset program where firms can trade avoided impacts and reclamation opportunities allows the market to reveal where the lowest opportunity cost options are while maintaining ecological benefit. Many offset protocols do not allow changes in the timing of activity to count as an offset, since it is difficult to quantify baselines above which avoidance could be counted as additional. This can lead to the perverse outcome that intact landscapes of high ecological value are often discounted or deemed ineligible for offset credits. While it is true that conservation offsets will result in leakage, we show that including conservation opportunities can greatly reduce the cost of an offset program, and also reduce ecological risks while reclamation benefits are proved and therefore should be considered, particularly in relatively undeveloped landscapes in which reclamation opportunities are limited.

Eligibility of offset actions are based on the costs and benefits of meeting the policy goal, rather than strict adherence to principles of additionality. Relaxing requirements for additionality allows biodiversity objectives to be achieved at a lower cost and may reduce ecological risk. Issues surrounding baselines and additionality often arise because there are not articulated clear conservation objectives related to the amount of ecological conservation society needs or wants. As a result offset programs are focused on achieving NNL at the project level by applying the principles of equivalence and additionality. This is, however, a project based approach to make up for a policy gap. An appropriate strategy for maintaining biodiversity would identify landscape objectives based on tradeoffs and design offset programs to achieve these objectives at least cost. This analysis shows that the offset design and ecological-economic tradeoffs associated with landscape objectives are interdependent decisions.

References

Alberta Biodiversity Monitoring Institute. (2009) Status of biodiversity in Alberta's Lower Athabasca Planning Region (00102), Version 2009-02-01. [WWW document]. URL www.abmi.ca

Alberta Biodiversity Monitoring Institute. (2011) Manual for estimating species and habitat intactness at the regional scale biodiversity intactness for species (20029), version 2011–07–07. [WWW document] URL www.abmi.ca

Alberta Boreal Conservation Offsets Advisory Group. (2009) Regulated conservation offsets with banking: a conceptual business model and policy framework. Unpublished Report submitted to Government of Alberta, Edmonton.

Alberta Geological Survey. (2009) Alberta Township System (ATS) and Universal Transverse Mercator

(UTM) Cartographic Conversion Tools. [WWW document]. URL http://www.ags.gov.ab.ca/gis/map_converters/conversion_tools.html

Alberta Ministry of Tourism, Parks and Recreation. (2006). Alberta's Boreal Forest Natural Region. [WWW document]. URL http://www.tpr.alberta.ca/parks/heritageinfocentre/naturalregions/borealforest.aspx

Alberta Sustainable Resource Development. (2005) Natural Region and Subregions of Alberta.

Bekessy, S., Wintle, B., Linenmayer, D.B., McCarthy, M., Colyvan, M. and Burgman, M. (2010) The biodiversity bank cannot be a lending bank. *Conservation Letters*, 3, 151–158.
Boreal Leadership Council. (2013) Canadian Boreal Forest Conservation Framework. Canadian Boreal Initiative. [WWW document]. URL http://www.borealcanada.ca/documents/FrameworkEnglish-December2013.pdf

BBOP (Business and Biodiversity Offsets Programme) (2009). Biodiversity Offset Design Handbook. BBOP, Washington, D.C. [WWW document]. URL www.forest-trends.org/biodiversityoffsetprogram/guidelines/odh.pdf

BBOP (2012) To No Net Loss and Beyond: an Overview of the Business and Biodiversity Offsets Programme. Forest Trends, Washington, DC [WWW document]. URL www.forest-trends.org/biodiversityoffsetprogram/guidelines/Overview_II.pdf

Brownlie, S., and M. Botha (2009) Biodiversity offsets: Adding to the conservation estate, or “no net loss"? Impact Assessment and Project Appraisal 27:227–231.

Bull, J.W., K. Suttle, N.J. Singh, and EJ Milner-Gulland. 2013. Conservation when nothing stands still: moving targets and biodiversity offsets. Frontiers in Ecology and the Environment. DOI:10.1890/120020

Bull, J.W., A. Gordon, E.A. Law, K. B. Suttle, and E.J. Milner-Gulland. 2014. Importance of Baseline Specification in Evaluating Conservation Interventions and Achieving No Net Loss of Biodiversity Conservation Biology. DOI: 10.1111/cobi.12243

Curran, M., S. Hellweg, and J. Beck. In press. Is there any empirical support for biodiversity offset policy? Ecological Applications. http://dx.doi.org/10.1890/13-0243.1

Canadian Association of Petroleum Producers. (2013) Crude Oil Forecast, Markets & Transportation. June 2013. 48 pp. [WWW document]. URL http://www.capp.ca/getdoc.aspx?DocId=227308&DT=NTV

Clare, S., N. Krogman, L. Foote, and N. Lemphers. 2011. Where is the avoidance in the implementation of wetland law and policy? Wetlands Ecology and Management 19:165–182.

Croft, Chad D., Todd Zimmerling, and Karl Zimmer (2011) Conservation Offsets: A Working Framework for Alberta Alberta Conservation Association, Sherwood Park, Alberta [WWW document]. URL http://www.ab-conservation.com/go/default/assets/File/Publications/ACA%20Conservation%20Offsets%20Framework%20Aug%202011.pdf

Crowe, M. and ten Kate, K. (2010) Biodiversity offsets: policy options for government. Business and

Biodiversity Offsets Programme. [WWW document]. URL http://www.forest-trends.org/documents/files/doc_3079.pdf

Cumming, S., Burton, P. and Klinkenberg B. (1996) Boreal mixedwood forests may have no "representative" regions: some implications for reserve design. *Ecography* **19**:162-180

Curran, M., S. Hellweg, and J. Beck. In press. Is there any empirical support for biodiversity offset policy? *Ecological Applications.* http://dx.doi.org/10.1890/13-0243.1

Dyer, S., Grant, J., Lesack, T., & Weber, M. (2008). Catching Up: Conservation and Biodiversity Offsets in Alberta's Boreal Forest. Canadian Boreal Initiative, Ottawa.[WWW document]. URL http://www.pembina.org/pub/1650

Department of Fisheries and Oceans (1985) Department of Fisheries and Oceans Act (R.S.C., 1985, c. F-15) Ottawa, Canada.

Department of Environment, Climate Change, and Water) (2009) Overview of the Biodiversity Credit Market. New South Wales, Australia. [WWW document]. URL www.environment.nsw.gov.au/resources/biobanking/099335creditmo.pdf

Environment Canada. (2011) Recovery Strategy for the Woodland Caribou, Boreal population (Rangifer tarandus caribou) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. vi + 55 pp.

Ferraro, P. J., and S. K. Pattanayak. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biology* 4:482–488.

Fox, J. and Nino-Murcia, A. (2005) Status of species conservation banking in the United States. *Conservation Biology*, 19, 996–1007

Gardner, Toby A., Amrei Von Hase, Susie Brownlie, Johnathan M.M. Ekstrom, John D. Pilgrim, Conrad E. Savy, R.T. Theo Stephens, Jo Treweek, Graham T. Ussher, Gerri Ward, and Kerry Ten Kate. 2013. Biodiversity Offsets and the Challenge of Achieving No Net Loss. *Conservation Biology*, Volume 27, No. 6, 1254–1264.

Gibbons, P., and D. B. Lindenmayer. 2007. Offsets for land clearing: No net loss or the tail wagging the dog? *Ecological Management and Restoration* 8:26–31.

Environment Canada. (2012) Operational Framework for Use of Conservation Allowances. [WWW document]. URL http://www.ec.gc.ca/ee-ea/default.asp?lang=En&n=DAB7DD13-1&printfullpage=true

Government of Alberta. (2008) Land-use framework. [WWW document]. URL https://www.landuse.alberta.ca/Documents/LUF_Land-use_Framework_Report-2008-12.pdf

Grant, J., Angen, E., and Dyer S. (2013) Forecasting the impacts of oilsands expansion Measuring the land disturbance, air quality, water use, greenhouse gas emissions, and tailings production associated with each barrel of bitumen production [WWW document] URL http://www.pembina.org/pub/2455

Habib, T.J., Farr, D.R., Schneider, R.R., and Boutin S. (2013) Economic and Ecological Outcomes of Flexible Biodiversity Offset Systems. *Conservation Biology* **27**:1313-1323.

Hauer, G.K., Cumming, S., Schmiegelow, F., Adamowicz, W., Weber, M., and Jagodinsk, R. (2010). Tradeoffs between forestry resource and conservation values under alternate policy regimes: A spatial analysis of the western Canadian boreal plains. *Ecological Modelling* **221**: 2590-2603.

Jentsch, A., Beierkuhnlein, C. and White, P.S. (2000) Scale, the Dynamic Stability of Forest Ecosystems, and the Persistence of Biodiversity. *Silva Fennica* **36**:393-400.

Mahon, C.L., Bayne, E.M., Sólymos, P., Matsuoka, S.M., Carlson, M., Dzus, E., Schmiegelow, F.K.A., Song, S.J. (2014) Does expected future landscape condition support proposed population objectives for boreal birds? *Forest Ecology and Management* **312**:28–39.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A. et al. (2012) Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation*, 155, 141–148

Nemes, V., Plott, C.R. and Stoneham, G. (2008) Electronic BushBroker Exchange: designing a combinatorial double auction for native vegetation offsets. [WWW document]. URL http://ssrn.com/abstract=1212202

Parkes, D., Newell, G., and Cheal, D. (2003) Assessing the quality of native vegetation: the ‘habitat hectares’ approach. *Ecological Management and Restoration* **S4**:29–38.

Pilgrim, J. D., et al. (2013) A process for assessing offsetability of biodiversity impacts. *Conservation Letters*: DOI:10.1017/ S003060531200172X.

Quétier, F., and S. Lavorel (2011) Assessing ecological equivalence in biodiversity offset schemes: Key issues and solutions. *Biological Conservation* 144:2991–2999.

Quétier, F., Regnery B., Levrel, H. (2014) No net loss of biodiversity or paper offsets? A critical review of the French no net loss policy. *Environmental Science and Policy* 38:120-131.

Royal Alberta Museum (2006). Natural Regions Description.Government of Alberta [WWW document] URL http://www.royalalbertamuseum.ca/vexhibit/eggs/vexhome_fr/regdesc.htm

Sedjo, R.A. and Marland, G. (2003) Inter-trading permanent emissions credits and rented temporary carbon emissions offsets: some issues and alternatives. *Climate Policy* **2**:435-444.

Schneider, R., and Dyer, S. (2006) Death by a thousand cuts: impacts of in situ oil sands development on Alberta's boreal forest. Pembina Institute. [WWW document]. URL www.pubs.pembina.org/reports/1000-cuts.pdf

Schneider, R. R., Hauer, G., Adamowicz, W.L. and Boutin, S. (2010) Triage for conserving population of threatened species: the case of woodland caribou in Alberta. *Biological Conservation* **143**:1603–1611.

Schneider, R. R., Hauer, G., Farr, D., Adamowicz, W.L., and Boutin, S. (2011) Achieving conservation when opportunity costs are high: optimizing reserve design in Alberta's oil sands region. *PLoS One* **6** DOI: 10.1371/journal.pone.0023254.

United States Department of the Interior. (2003) Guidance for the Establishment, Use, and Operation of Conservation Banks, Fish and Wildlife Service, Washington, D.C. 20240.

Watts, M.E., Ball, I.R., Stewart, R.S., Klein, C.J., Wilson, K., Steinback, C. (2009) Marxan with Zones: Software for optimal conservation based land- and sea-use zoning. *Environmental Modelling and Software.*

Weber, M., Farr, D., Hauer, G., Nemes, V., and Perger, O. (2011) Experimental Economic Evaluation of Offset Design Options for Alberta. [WWW document] URL https://www.landuse.alberta.ca/LandUse%20Documents/Experimental%20Evaluation%20of%20Offset%20Design%20Options%20Research%20-%202011-11.pdf