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Can carbon accounting promote economic development in forest-dependent, indigenous communities?

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ABSTRACT

Forest-dependent, rural communities often experience declining populations and economic prosperity because technological changes related to harvesting, transportation and processing of wood fiber have increased the capital investments required while reducing employment. How then can communities, where forest resources are the primary economic driver, increase wealth that might then be used for economic development? Answers to this question are explored by examining the potential of different forest management regimes to create greater employment and wealth, particularly management options that include carbon values. Our application is to an interior forest region of British Columbia, the region that produces the greatest volume and value of lumber for export and the province where indigenous peoples have not ceded aboriginal title to most of the land base on which the trees grow. While traditional practices of managing forests primarily used to be multi-functional and sustainable, the results of our study are less optimistic. We examine the trade-offs and potential synergies between revenue (as measured by net present value), employment and carbon in forest ecosystems, where the latter is a proxy for the ecological health of the forest. We conclude that no management strategy is able to satisfy all of the technical, environmental and social/cultural constraints and, at the same time, offer forest-based economic development that will prevent the decline of rural communities.

1. Introduction

In Canada, governments have historically enhanced economic development in rural regions by promoting exploitation of natural assets, including forest resources. Many rural communities depend on the forest industry,[1] with a significant number reliant on forestry for > 50% of household income. Indeed, forest resources are an economic development driver in many of the > 80% of non-native communities located in forest regions.[2] Forests also provide indigenous people with cultural and spiritual values, and non-timber forest amenities (e.g., biodiversity, wildlife harvests for meat and fur, salal berries, etc.), whose values can be satisfied by maintaining a certain amount of mature, old-growth tree stands. While this is especially important when considering the health and sustainability of forest-dependent, indigenous communities (Beckley et al. 2002), the strategy may be incompatible with timber exploitation.

Moreover, while the non-market amenities of forests are important for indigenous peoples, high rates of unemployment and low incomes often characterize First Nations' communities, leading to poverty and a failure to meet indigenous peoples' aspirations to a certain level of material wellbeing. For example, 42.9% of dwellings on First Nations' lands, which include forest-dependent communities, have defective plumbing or electric wiring and/or need structural repairs to walls, floors or ceilings. Therefore, it is necessary to determine means by which forest resources can be used to increase community incomes and employment (Krcmar et al. 2005, 2006; Krcmar and van Kooten 2008).

Statistic Canada's 2011 National Household Survey found that there were 1.4 million indigenous people living in Canada, representing 4.3% of the country's total population. This was up from 3.8% of the population in the 2006 Census, 3.3% in 2001, and 2.8% in 1996. However, rates of unemployment among indigenous peoples in Canada are significantly higher than they are for Canadians as a whole. This is shown in Fig. 1, where unemployment rates are provided for Canada as a whole, plus the two provinces that have the greatest proportion of indigenous people in the population, Saskatchewan and Manitoba. Unemployment rates in more remote, forest-dependent communities, and particularly First Nations' communities, are much higher, sometimes over 50% higher especially among those under age 25, while labor

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[1] Kluvánková et al. (2018) identify 'forest-dependent communities' as communities living in marginalized rural areas in close relationships with forests, which provide them a variety of ecosystem services, and the well-being of such communities (in its wider sense) is directly and positively dependent on the forestry sector's sustainability.

[2] Unless otherwise indicated, data provided in the Introduction come from Statistics Canada's National Household Survey, 2011.

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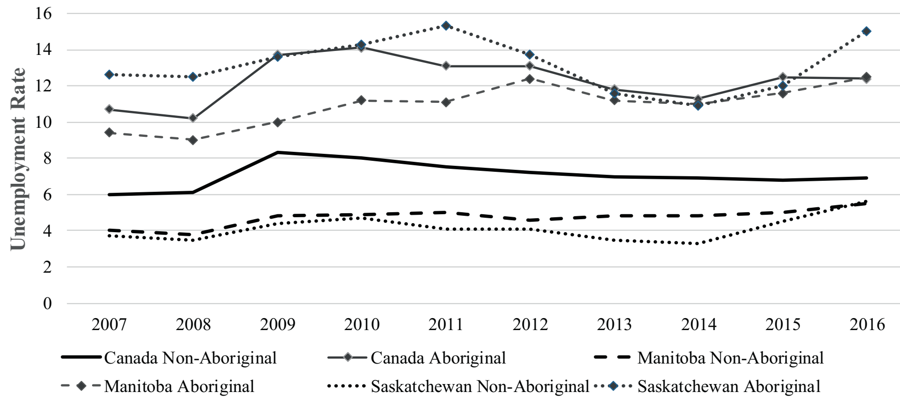

Fig. 1. Unemployment Rates for Non-Aboriginal and Aboriginal People, Canada and Selected Provinces, 2007–2016.
(Source: Statistics Canada, Labour Force Survey, CANSIM Table 282–0226)

force participation rates are much lower, thereby indicating that actual unemployment is likely even greater – potential workers are discouraged by their employment prospects and simply drop out of the labor force. In 2011, the off-reserve unemployment rate for aboriginals was 34% percent, but it was 53% for those living on reserves.

Governments have sought to address poverty on reserves, especially in forest-dependent indigenous communities, by allocating greater control over timber harvests to First Nations. Between 2003 and 2014, the proportion of the sustainable timber harvest in Canada allocated to First Nations increased from 4.7% to 10.4%, as indicated in Table 1. At the same time, efforts are underway to provide indigenous peoples with the skills needed to work in the forest sector in occupations ranging from forest management, silviculture and harvesting to mill operations, manufacturing and marketing, replacing many workers who will retire in the near future (Forest Products Sector Council 2011; Natural Resources Canada 2016). Already indigenous people account for 17,000 direct and indirect jobs in the forest sector (or 5.3% of the total compared to 3% on average in other sectors), while indigenous forest enterprises now number between 1200 and 1400, or some 15% of all forestry enterprises. The highest total harvests and First Nations' allocations are in British Columbia, which is why we selected an interior BC forest region as our case study.

The purpose of the current paper is to investigate a particular aspect of the role that forestry has in providing income, employment (e.g., logging and transportation jobs), and ecological-environmental services (perhaps of a cultural nature). Of course, income and employment are important to forest-dependent, indigenous communities, without which First Nations' peoples cannot satisfy minimal material desires and may not even be able to benefit adequately from other forest ecosystem services. Further, whereas income and employment can easily be measured, ecological and cultural benefits are of a non-market nature (see Nijnik and Bizikova 2008; Nijnik and Miller 2014). Because they are difficult to measure, in the current application, we use net carbon uptake as a proxy for such benefits; in essence, we equate the ecological service benefits accruing to indigenous peoples with the role their local forest ecosystems play in mitigating climate change (see Krcmar et al. 2005, 2006). We do this despite carbon offset credits constituting an income benefit; as we demonstrate below, these are not identical objectives.

While others have examined the importance of forest-sector employment in First Nations and even considered the role of forests in mitigating climate change (e.g., Krcmar and van Kooten 2008), the current research employs a more sophisticated and realistic model of carbon fluxes to answer several research questions that still merit attention. By taking into account potential benefits of carbon offset trading, we examine the trade-off between employment and income, and between these and our proxy for ecosystem benefits (carbon flux). A secondary question relates to whether employment in the forest sector or net forest rents are adequate enough to drive economic development and support population growth in remote forest-dependent communities.

We begin in the next section by describing the research methods. A forest management model is developed to maximize net discounted returns to commercial timber operations plus the benefits of managing carbon fluxes. The model tracks carbon in living trees, organic matter and post-harvest carbon pools, and counts the avoided emissions from substituting wood for non-wood in construction or bioenergy for fossil fuels. Constraints ensure that forest management is sustainable, while carbon prices ensure efficient mitigation of climate change. The study area and data are described and then nine scenarios are examined. In each scenario, we determine (1) the maximum NPV and associated employment and carbon uptake, (2) the maximum potential

Table 1
National Allocation of Forest Tenure Volume to First Nations, Selected Years, 2003–2014.
Source: Compiled from data provided by the National Aboriginal Forestry Association (2015).

Region	Total Harvest Allocation (million m^3/yr)			Proportion Native (%)			% of Total Native Allocation[a]
	2003	2006	2014	2003	2006	2014	
Quebec	35.7	31.8	17.2	1.8	2.7	6.9	6.3
Ontario	30.5	22.6	29.2	3.6	5.7	14.1	22.1
Manitoba	3.5	3.5	2.5	3.8	4.5	15.3	2.0
Saskatchewan	6.8	8.1	8.3	16.8	24.3	42.2	18.6
Alberta	24.1	24.6	32.0	4.1	4.7	3.3	5.4
British Columbia	61.3	82.6	81.7	6.1	7.3	10.8	47.3
Rest of Canada	8.7	9.7	13.4	0.03	0.03	0.04	1.6
Total Canada	170.6	182.8	184.2	4.7	6.4	10.4	100.0

[a] Proportion of total Canadian timber volume allocated to First Nations in 2013/14 (19,199,333 m^3) attributed to the jurisdiction in the left column. Weighted average allocation to First Nations equals 10.4%.

employment and associated NPV and carbon uptake, and (3) the maximum carbon uptake and associated NPV and employment. A static comparative analysis indicates the influence that key variables have on the results.

The research indicates that forest-dependent, rural communities can benefit greatly in terms of increased net income when the price of carbon offset credits is used to incentivize lower CO_2 emissions and increase sequestration of carbon through forestry activities. Prospects for reducing poverty in forest-dependent, indigenous communities through different management of forests are less optimistic, partly because of rapid population growth. There is not enough evidence to argue that strategies to protect forests to take advantage of the sale of carbon offset credits would yield significant financial benefits that could be used to reduce poverty. The paper concludes by offering some insights into the feasibility of promoting economic development in forest-dependent, indigenous communities through carbon accounting and by providing some insights into where this might lead in the future.

2. Methods and materials

In this section, we adapt a holistic forest management model by van Kooten (2018) that accounts for carbon flows. The objective is to maximize the net present value of commercial forest operations plus the financial benefits from creating carbon offset credits to sell in carbon markets. Alternative objectives are to maximize the sustainable level of employment and the net carbon sequestered. We then determine trade-offs between the financial objective and the employment and environmental objectives, and where a compromise solution might lie. The results are then used to determine the potential for forestry to sustain forest-dependent communities.

The results of the analysis depend to a large degree on assumptions regarding the creation of carbon offset credits. This decision is a political one that depends on what activities can be used to create carbon offsets and what substitutions are permitted and how these are counted – that is, can one claim carbon credits for fossil fuel emissions avoided when wood biomass is used to generate electricity or emissions associated with production of steel and cement when wood substitutes for non-wood materials in construction? It also depends on how urgent the need is to address climate change and the rate used to discount future carbon fluxes (see below). The application is to the Quesnel Timber Supply Area in the interior of British Columbia, as the majority of indigenous harvest occurs in BC's interior, even though this region represents a more productive forest, than the boreal forest, where many First Nations' forest-dependent communities are found.

2.1. Forest Management Model

The forest management model employed here is described in van Kooten (2018) and is built on an earlier version for a different region by van Kooten et al. (2015). The forest management model consists of a constrained optimization problem formulated as a linear programming model. We assume that an indigenous decision maker (DM) can make decisions related to the forest independent of any other layer of authority, except, of course, the 'authority' of a private-sector certifier such as the Programme for the Endorsement of Forest Certification (perhaps Forest Stewardship Council). The indigenous DM is assumed to be able to capture all of the rents accruing to forestry operations and thus is assumed to maximize the following objective:

$$NPV = \sum_{t=1}^{T} \beta^t \left[\left(\sum_{j=1}^{N} p_j \varepsilon_j \right) H_t - K_t - p_C (E_t - C_t - S_t) \right], \quad (1)$$

where NPV is net present value. Further, H_t refers to the harvest (m^3), p_j to the price of forest product j ($\$/m^3$), ε_j is the proportion of the harvest processed into product j, p_c to the price of carbon ($\$/tCO_2$), and $\beta = 1/(1+r)$ is the discount factor, with r the discount rate on monetary values. For simplicity and given fixed product prices and proportions ε_j, it is assumed that the price of logs ($\$/m^3$) equals $\left(\sum_{j=1}^{N} p_j \varepsilon_j\right)$ and is the value of interest in the objective function (1). That is, logs are processed into lumber, with wood chips and other residues used to make pulp, manufacture engineered wood products (e.g., oriented strand board or OSB, and fiber board), and wood pellets for energy; these products are assumed to be produced in fixed proportions. It is also assumed that all employment generated as a result of logging, transportation and processing accrues to indigenous peoples.

Further, K_t refers to the costs of forest management, silviculture, harvesting, hauling, processing and administration costs – the costs of processing logs into wood products and creating carbon offset credits. Then E_t refers to the emissions released as a result of forestry activities. Finally, C_t and S_t refer, respectively, to the carbon flux and emissions avoided because of the reduced production of cement and steel if wood substitutes for these materials in construction, or if wood biomass substitutes for fossil fuels in the generation of electricity. Carbon flux and substitution (avoided emissions) are measured in metric tons of carbon dioxide (tCO_2).

The measurement of CO_2 fluxes at time t needs further explanation. Suppose a forest site is harvested, the logs hauled to a sawmill and then processed only into lumber and wood pellets. The emissions related to harvest, hauling and processing are taken into account by the term E_t in Eq. (1). Changes in the ecosystem carbon are taken into account, using the Canadian Forest Service's Carbon Budget Model (Kull et al. 2011), although these are explicitly embodied in the BC government's growth and yield calculator, TIPSY.[3] These carbon fluxes are included in the C_t term in Eq. (1). The remaining components of C_t depend on the final disposition of logs.

When trees are harvested, it is assumed that all of the carbon stored in the trees is immediately (at time of harvest t) released to the atmosphere. Of course, this is not the case; if timber is processed into lumber, the carbon is stored and only slowly released into the atmosphere. If carbon is released to the atmosphere from a wood product 80 or more years after the time of harvest, it has little if any impact on climate change. Therefore, its contribution to global warming and today's carbon flux is insignificant, and should be weighted much less than if that same amount of carbon was released (in the form of CO_2) one year after harvest. Future carbon flux from production of lumber or another long-lived wood product must be discounted to the common year of harvest, and the rate used to do this largely depends on the urgency with which society wishes to address climate change.[4] If there is some urgency to address climate change, then current CO_2 emissions are more dangerous than future ones and current carbon uptake is more beneficial than future sequestration. The more urgent the need to address climate change, the higher must be the rate used to discount future physical carbon uptake from and release to the atmosphere.

The weighted current carbon released from and stored in a post-

[3] TIPSY (Table Interpolation Program for Stand Yields) is a growth and yield model developed by the BC Ministry of Forests that provides yield tables for stands under different management regimes using TASS (Tree and Stand Simulator) and economic data using SYLVER (Silviculture on Yield, Lumber Value, and Economic Return) (BC MFLNRO 2016).

[4] The use of weights to discount physical flows originates with Ciricacy-Wantrup (1968), and the need to discount physical carbon is now well established (Richards 1997; Schlamadinger and Marland 1999; Nijnik and Pajot 2014; Johnston and van Kooten 2015); indeed, van Kooten (2018) considers the discount rate on carbon fluxes to be a policy instrument to be specified in determining carbon credits. Even non-economists discount carbon; Helin et al. (2013) write that the "advantage of the GWP [global warming potential] approach is that it provides a kind of physically based discounting factor *by which the biomass emissions with deviating timing can be transformed into a permanent fossil carbon emission whose cumulative warming impact within a given time horizon is the same*" (p.481, emphasis added).

harvest wood product pool at time of harvest t is given by (van Kooten 2018):

$$C_{t,release} = \left(\frac{d}{r_c + d}\right)\varepsilon C \text{ and } C_{t,stored} = \left(\frac{r_c}{r_c + d}\right)\varepsilon C, \quad (2)$$

where d is the rate at which the wood decays, C is the amount of carbon in harvested timber and ε is the proportion the timber entering the product pool. If $d = 0$ (no decay) then the amount of carbon released from products is also zero and all the carbon is retained regardless of the rate used to weight carbon. If $r_c = 0$, no carbon is stored because it is all released. The same reasoning applies to biomass burning and subsequent uptake through new growth, except this is taken into account within the model by new plantings and subsequent uptake of carbon from the atmosphere. The choice of r_c is clearly a political one as it depends on the urgency with which society wishes to address climate change, as opposed to the choice of the discount rate used to discount monetary values (including the value of carbon offset credits), which depends on market outcomes.

The CO_2 emissions avoided when wood pellets substitute for fossil fuels in the generation of electricity, or the emissions avoided in producing steel and concrete when wood substitutes for these materials in construction, might also be counted as savings attributable to the forestry activities. In both cases, however, these emissions reductions might more appropriately be counted in other sectors of the economy. Again, the decision to provide carbon offset credits for emissions avoided, and the degree of substitution, is a political one (van Kooten 2018).

Finally, the model also includes various technical constraints; these relate to the limits on harvest imposed by the available inventories in any period, based on tree species, bio-geo-climatic zones, slope classes and age characteristics; there is a total area constraint; constraints on growth from one period to the next (which are affected by management practices); reforestation options; limits on the minimal merchantable volume that must be stocked before harvest can occur; sustainability constraints (viz., sustainable management certification standards); nonnegativity constraints; and other constraints relating to the scenarios that are investigated. The constrained optimization model is constructed in GAMS (General Algebraic Modeling System) and solved using the CPLEX solver (Rosenthal 2008).

2.2. Study area and data description

British Columbia produces the most timber of any province in Canada with 95 million ha of forestland (27.3% of Canada's total), a harvest of 66.5 million m^3 (43.4%), and exports of more than \$10.8 billion (50.4%) (Natural Resources Canada–Canadian Forest Service 2016). It is no wonder that the majority of the timber made available to indigenous peoples is located in the province (see Table 1). The Quesnel Timber Supply Area (TSA) is located in the Northern Cariboo Forest Region in the Southern Interior of BC and covers some 1.4 million ha, of which 965,700 ha are in the harvest land base, consisting of Lodgepole pine (85%), spruce (10%), Douglas-fir (3%) and a variety of other species (Snetsinger 2011).

To keep the model manageable, we identified 538 sites in the Quesnel TSA, but there was no information about the proportions of major and secondary species. Therefore, the proportions of major and secondary species were randomly derived and the TIPSY model used to simulate growth and yield for 200 years (using a decadal time step) and for two treatments after harvest – stands regenerated with enhanced stems planted over a two-year period or regenerated with natural growing stock (basic silviculture) within six years of harvest. This resulted in a forest with 6205 stands covering an area of 20,266.4 ha that was most representative of the Quesnel TSA. As noted earlier, the Canadian Forest Service's Carbon Budget Model was used within TIPSY to track carbon fluxes and stocks in living and dead biomass in the forest ecosystem over time.

In 2014, total timber harvest in the BC interior amounted to 46.92 million m^3; this translated into 18.2 million m^3 of lumber. Sawmill residues constituted 21.3 million m^3, with the remaining 7.4 million m^3 consisting of logs that were chipped directly or made into a variety of engineered wood products. The recovery of lumber varies by size and species of trees, and is taken into account in the growth and yield data from TIPSY. Fixed proportions are assumed for the disposition of residues, however. While some residues (particularly sawdust) are burned at mills for heat and electricity, and/or converted to wood pellets, the majority of residuals are used to make pulp. Based on a 2014 survey of interior BC mills (BC MFLNRO 2015), it is assumed that 15.1% of residues are used to manufacture various wood products, 69.7% is directed to pulp mills, and the remaining 15.2% is used to produce biofuels, mainly wood pellets.

The costs of converting standing trees into lumber, sawmill residues and chips is the sum of the harvesting costs, road and infrastructure costs, transportation costs, manufacturing costs, and costs of post-harvest treatment of the site; these are summarized in Appendix Table A1. Also, summarized in Table A1 are the price and cost data used in the study. Lastly, rates of CO_2 emissions and decay rates for various forest carbon pools are provided in Appendix Table A2.

The CO_2 released when producing a megawatt hour (MWh) of electricity varies by fuel type. Natural gas releases 0.55 tCO_2/MWh of power, while coal releases 0.94 tCO_2/MWh. On average, wood biomass with a moisture content of 40% would generate 1.83 MWh of electricity per m^3 (Kofman 2010). Burning wood in lieu of natural gas would save 1.01 tCO_2/m^3, and 1.72 tCO_2/m^3 if bioenergy replaced coal. Wood burning is considered carbon neutral in legislation, so emission reductions from burning wood in lieu of a 50–50 mix of natural gas and coal to generate electricity amount to 1.365 tCO_2/m^3 (van Kooten 2018). Finally, if wood substitutes for non-wood materials in construction, the emissions avoided from not producing steel and concrete could be as high as 3.3 tCO_2/m^3 (Hennigar et al. 2008), although we use an average of 2.75 tCO_2/m^3.

3. Results

Nine scenarios were examined, including a baseline scenario where carbon is unpriced. In each scenario, we found (1) the maximum NPV and associated employment and carbon uptake, (2) the maximum potential employment and associated NPV and carbon uptake, and (3) the maximum carbon uptake and associated NPV and employment. The results are provided in Tables 2 and 3 for carbon prices of \$50/tCO_2 and \$100/tCO_2, respectively. The maximum values of the objectives are in bold in each scenario. This then allowed us to determine the opportunity cost of creating additional direct plus indirect indigenous jobs in terms of potential net discounted returns that the indigenous forest owner could make over the 200-year life of the forest.[5] We also found the marginal cost (MC) of our crude environmental benefit in terms of the NPV that would be forgone to ensure the greatest possible carbon uptake. This was measured in terms of \$/tCO_2. These results are provided in Table 4.

It is not unusual for governments to focus on jobs rather than net revenues, and that managing a forest for its net discounted commercial benefits reduces employment. What might the required monetary sacrifice entail? Given the results in Table 2, we find that the sacrifice varies from less than about \$800 per job to as much as \$11,270, where the sacrifice might include the benefits the landowner would have

[5] Delcourt and Wilson (1998) estimate that 1000 m^3 of harvest resulted in one forest-related job in 1993. They include logging and downstream manufacturing employment, but not jobs in other sectors. Given labor-saving technological advances in the past 25 years, we apply their estimate to include indirect (non-forest sector) jobs.

Table 2
Trade-offs When Maximizing Net Present Value, Employment and Net Carbon Uptake, Objective Values, Baseline and Various Scenarios where P_{carbon} = \$50/tCO_2[a].
Source: Authors' calculations.

Objective that is maximized	Value of Objectives		
	NPV (\$ mil)	Employment ('000 s)	Discounted Carbon (Mt CO_2)
Baseline: Pcarbon = \$0/tCO₂			
NPV	**159.20**	10.77	2.776
Employment	145.32	**16.52**	3.317
Carbon Uptake	102.86	5.63	**3.891**
No substitution			
NPV	**176.51**	10.03	3.503
Employment	171.27	**16.52**	3.317
Carbon Uptake	153.53	5.63	**3.891**
Substitute for fossil fuel burning; count emissions avoided			
NPV	**190.79**	9.99	3.967
Employment	185.09	**16.52**	3.848
Carbon Uptake	179.59	7.36	**4.239**
Substitute wood for non-wood in construction; count emissions avoided			
NPV	**350.77**	14.01	9.181
Employment	336.62	**16.52**	9.531
Carbon Uptake	343.05	16.36	**9.612**
Substitute biomass for fossil fuels in electricity& wood for non-wood in construction; count emissions avoided			
NPV	**365.79**	14.18	9.724
Employment	350.45	**16.52**	10.063
Carbon Uptake	357.90	16.35	**10.151**

[a] Numbers in bold indicate the maximum value of the objective. Net carbon uptake would equal the number of carbon offsets created.

Table 3
Trade-offs when maximizing net present value, employment and net carbon uptake, objective values, P_{carbon} = \$100/tCO_2, various scenarios[a].
Source: Authors' calculations.

Objective that is maximized	Value of Objectives		
	NPV (\$ mil)	Employment ('000 s)	Discounted Carbon (Mt CO_2)
No substitution			
NPV	**210.05**	8.39	3.791
Employment	197.22	**16.52**	3.317
Carbon Uptake	204.21	5.63	**3.891**
Substitute for fossil fuel burning; count emissions avoided			
NPV	**233.87**	9.73	4.141
Employment	224.86	**16.52**	3.848
Carbon Uptake	231.15	7.36	**4.239**
Substitute wood for non-wood in construction; count emissions avoided			
NPV	**545.88**	14.82	9.353
Employment	527.92	**16.52**	9.531
Carbon Uptake	539.25	16.36	**9.612**
Substitute biomass for fossil fuels in electricity& wood for non-wood in construction; count emissions avoided			
NPV	**575.29**	14.77	9.887
Employment	555.57	**16.52**	10.063
Carbon Uptake	568.02	16.35	**10.151**

[a] Numbers in bold indicate the maximum value of the objective. Net carbon uptake would equal the number of carbon offsets created.

received from sale of carbon offset credits. Assuming an average annual income of \$50,000, the cost of creating extra jobs varies from 1.6% to 22.5% of earnings; the former is likely acceptable in First Nations' communities, while the latter is harder pill to swallow.

Surprisingly, the lowest cost of creating jobs occurs when the policymaker permits no carbon credits to be issued for substitution of fossil fuel emissions avoided in other sectors, or when the forester can count emissions avoided from substituting biomass (wood pellets) for fossil fuels in the generation of electricity. This is the case regardless of the fact that more carbon offset credits are created in these two instances when NPV is maximized rather than employment (see Table 3). Yet, when carbon credits are provided for the fossil fuel emissions avoided when wood substitutes for steel and concrete in construction, the costs of creating additional jobs is at its greatest. This is the case even though net discounted emissions of carbon (carbon offset credits created) are lower when NPV is maximized than when employment is maximized. Indeed, the cost of additional jobs then accounts for about one-fifth of total earnings.

When the objective is to maximize employment (or timber harvests given 1000 m^3 harvest = 1 job), commercial harvests increase by between 12% (under a high price of carbon and when carbon offset credits include fossil fuel emissions avoided when wood biomass is burned for electricity and when less concrete and steel is used when wood substitutes for non-wood in construction) and 96% (high price of carbon but no carbon offsets permitted from substitution). While greater utilization of the forest is inevitably linked to forest degradation, this does not appear to be the case here, at least if ecosystem carbon is any indication (see Table 5). Greater utilization not only leads to more jobs, but it also appears to lead to more ecosystem carbon – more fast growing vegetation, logging residues and organic soil carbon, but at an increased cost in net discounted revenues.

Not surprisingly, when CO_2 emissions avoided in other sectors cannot be attributed to forestry activities, or when credit is given only in the case where biomass is used to generate electricity, the carbon stored in the product pool is lower under the NPV scenarios than otherwise. When avoided emissions from reduced production of steel and concrete are taken into account, there will be greater substitution of wood for non-wood materials in construction, thereby leading to more carbon stored in products under the NPV scenario (Table 5).

The results of our analysis also indicate that carbon in ecosystems (excluding carbon in product sinks) is greatest when the indigenous landowner maximizes net carbon sequestration and, at the same time, policymakers incentivize the landowner to take into account the CO_2 emissions saved when wood substitutes for non-wood in construction. Otherwise, ecosystem carbon is maximized when the decision maker maximizes employment. This is surprising because employment and protection of the environment are often seen as contradictory objectives; but, in this case, they are not.

In our model, we imposed a sustainable harvest constraint by requiring the harvests in each decade to be within plus or minus 10% of that in the first decade, where the harvest in the first decade is endogenously based on the calculated mean annual increment (harvest equals growth); subsequent harvests are also endogenously determined. When this 'even-flow' constraint is not imposed, harvests vary greatly from one decade to the next, which is what is expected when one begins with an uneven-age forest. If a sustainable harvest constraint is imposed, the model harvests are nearly the same in each period, regardless of the objective chosen.[6] Compared to the case of even-flow management, the objective values for NPV, employment and net carbon removed from the atmosphere are all higher when there is no sustainability constraint. The 'even-flow' results are provided in Appendix, Tables A3 through A6.

With sustainable management, the employment is much lower at

[6] Government forestland owners implement community stability by specifying even-flow constraints. This is true for the Quesnel TSA, where even-flow harvests are determined by timber supply analyses and characterized by five-year plans and sustainability requirements where the allowable cut defined in terms of annual growth rates. However, even flow does not guarantee community stability because companies substitute capital for labor, and markets and lumber prices disrupt the relation between even-flow and community stability (see also Krcmar et al. 2006).

Table 4
Trade-offs between net present value objective and (i) employment and (ii) environmental objectives, opportunity cost of job creation and carbon sequestration, various scenarios.
Source: Authors' calculations.

Scenario	Cost of job ($'000 s)	MC carbon ($/t$CO_2$)	Cost of job ($'000 s)	MC carbon ($/t$CO_2$)
Baseline	2.41	50.53		
	P_{carbon} = $50/t$CO_2$		P_{carbon} = $100/t$CO_2$	
- No substitution	0.81	59.23	1.58	58.40
- Substitute for fossil fuel burning; count emissions avoided	0.87	41.18	1.33	27.76
- Substitute wood for non-wood in construction; count emissions avoided	5.64	17.91	10.56	25.60
- Substitute biomass for fossil fuels in electricity & wood for non-wood in construction; count emissions avoided	6.56	18.48	11.27	27.54

Table 5
Carbon savings due to forestry activities, net total, ecosystem and stored in products at carbon prices of $50/t$CO_2$ and $100/t$CO_2$, Mt CO_2[a].
Source: Author calculations.

	Net Total			Ecosystem			Stored in Products		
Scenario / Objective →	NPV	Employ	Carbon	NPV	Employ	Carbon	NPV	Employ	Carbon
Baseline	2.776	3.317	3.891	5.627	6.284	5.751	1.238	1.308	0.831
	P_{carbon} = $50/t$CO_2$								
No substitution	3.503	3.317	3.891	6.257	6.284	5.751	1.212	1.308	0.831
Substitute for fossil fuel burning	3.967	3.848	4.239	6.229	6.284	6.087	1.215	1.308	0.993
Substitute wood for non-wood in construction	9.181	9.531	9.612	6.013	6.284	6.308	1.332	1.308	1.327
Substitute both	9.724	10.063	10.151	5.994	6.284	6.307	1.335	1.308	1.331
	P_{carbon} = $100/t$CO_2$								
No substitution	3.791	3.317	3.891	6.079	6.284	5.751	1.020	1.308	0.831
Substitute for fossil fuel burning	4.141	3.848	4.239	6.261	6.284	6.087	1.140	1.308	0.993
Substitute wood for non-wood in construction	9.353	9.531	9.612	6.112	6.284	6.308	1.343	1.308	1.327
Substitute both	9.887	10.063	10.151	6.093	6.284	6.307	1.344	1.308	1.331

[a] The values in the table are discounted carbon flows.

13,800 jobs per year than if harvests are allowed to vary over time, so that investment in new forests can occur; in that case, 16,200 jobs are provided each year on average. Of course, this does not account for potential changes in technology that reduce the number of workers supported by 1000 m^3 of harvest from one (as assumed here) to a smaller number.

4. Concluding discussion

In this paper, we examined the potential for forest resources to be a driver of economic development in forest-dependent, indigenous communities in Canada. In doing so, we investigated the role that carbon accounting could play in improving the prospects for development, either through greater forest-based activities that create jobs or via the additional wealth that is achieved from the creation of carbon offset credits. Given the assumptions, constraints and context specificity of the current research, and regardless of what strategy is adopted, forestry is unlikely to become an engine of economic growth for remote indigenous communities. At best, $206.6 million of NPV can be created, but, when spread over a very long time horizon, it amounts to some $8 million to $20 million annually (depending on the discount rate employed), and then under the condition that the indigenous decision maker manages the forest to maximize the discounted net returns it receives. If the indigenous DM is concerned about community sustainability, in which case an even-flow directive is generally followed, the maximum NPV that sale of carbon credits would realize is $187.1 million, or $7.5–$18.7 million annually. While these sums are not insignificant, they come about only from sale of carbon offset credits.

While we conclude that no management strategy considered in this research is able to satisfy all of the technical, environmental and social/cultural constraints and, at the same time, offer forest-based economic development in indigenous rural communities, knowledge of trade-offs among objectives may be important nonetheless. Such knowledge helps to identify management options that can suggest ways to improve upon current employment, wealth and/or ecological health of the forest. For example, in some scenarios carbon sequestered in the ecosystem is maximized when employment is maximized. This suggests that, to the extent cultural and other forest attributes considered important to indigenous peoples are related to in situ forest carbon, an indigenous DM might wish to focus on maximizing employment rather than wealth, assuming of course that indigenous people benefit from enhanced employment opportunities.

Our results hinge on the resolution of at least two issues related to property rights. First, we assumed that the DM had complete rights to manage the forest for the benefit of indigenous peoples, deciding on harvest levels, collecting available forest rents and providing employment to members of the indigenous community. The only constraint on the DM was a requirement to sustainably manage the forest. It is beyond the scope of the current research to determine the extent to which property rights might ever be allocated to First Nations, nor the degree to which they would be able to take advantage of employment opportunities they might create. Second, we assumed that it is possible to award carbon credits in seamless fashion, and that such credits could be sold on carbon markets. This would require the existence of a mechanism for flawless measurement of carbon fluxes and markets in which carbon credits are bought and sold.

Finally, forestry will necessarily remain a legitimate means for promoting economic development and alleviating poverty, although, as demonstrated in this paper, progress in this direction is likely to be limited. This is especially true in forest-dependent, indigenous communities where residents are likely to have a cultural tie to the resource – to place – compared to those in non-indigenous, forest-dependent communities. This suggests that policies applied to the non-indigenous rural community might not be relevant for First Nations peoples living in similar circumstances.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2018.10.012.

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[7] More information about the EU-funded Horizon 2020 project SIMRA (Social Innovation in Marginalized Rural Areas) is available at: www.simra-h2020.eu