## Reply to 'Clarity of meaning in IPCC press conference'

**Pearce and Hollin reply** — Scientific information about climate change has proved to be a relatively poor motivator for meaningful public action[1,2]. That Jacobs *et al.*[3] critique our recent Letter[4] about public meanings attached to abstract scientific knowledge by using even more abstract scientific knowledge reaffirms this central point: that some in the climate science community fail to understand that scientific knowledge alone, no matter how certain, is poorly equipped to meaningfully communicate climate change.[5].

Continuing this misplaced focus on certainty, much of the Jacobs *et al.* correspondence gives supporting scientific evidence for the claims of certainty made by speakers during the press conference for the Working Group 1 contribution to the Fifth Assessment Report of the IPCC. However, such evidence is superfluous, as we do not argue in our Letter that short-term events such as 'the pause' undermine any well-established certainty. Rather, we examine, first, the attempts of press conference speakers to make well-established certainty meaningful and, second, the resulting confusion among journalists as to what constitutes valid scientific evidence. This confusion seems to leave Jacobs *et al.* untroubled, as they ignore it in their Correspondence.

Instead, we highlight that the '30-year rule' is used flexibly during the press conference. Emphasizing the past decade, as IPCC speakers do, may well help to make anthropogenic global warming meaningful and potentially motivational for action[6]. However, this emphasis on the decadal scale also seems to makes journalists' questions about 'the pause' both reasonable (because it is also decadal in scale) and meaningful (for it might seem to demotivate action). If asking about the decade-long pause is an "ill-posed scientific question", as asserted by Michel Jarraud during the press conference, then using the past decade of heat and extremes to emphasize the meaningfulness of anthropogenic global warming is not scientifically appropriate. It is the resulting confusion among journalists, caused by the flexible application of the '30-year rule', that illuminates the tension between certainty and meaning faced by climate communicators.

We also disagree that we misrepresent particular quotes in our Letter. First, a quote from former IPCC chair Rajendra Pachauri is said by Jacobs *et al.* to require contextualization. This particular portion of the press conference transcript was selected because it is illustrative of references to the warmest decade made by all three speakers. Second, Jacobs *et al.* suggest that we present a quote as concerning 'the pause' when it does not. This is not the case. The quote appears within a general discussion of technical uncertainty[7,8] (within Supplementary Data C of our Letter[4]) that does not refer exclusively to the pause.

We hope that through restating our central argument this response has assisted in clarifying our original analysis. Excellent examples do exist of making climate change publicly meaningful through the acceptance and accommodation of uncertainties in science[9–12]. Sadly, the press conference in question was not such an example. ❐

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### Additional information

Supplementary information is available in the online version of the paper.


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COMMENTARY:

# Megaproject reclamation and climate change


Rebecca C. Rooney, Derek T. Robinson and Rich Petrone



**Megaprojects such as oil sands mining require large-scale and long-term closure and reclamation plans. Yet these plans are created and approved without considering future climate and hydrological conditions, jeopardizing the sustainability of reclaimed landscapes.**


Resource extraction megaprojects are defined by their massive operational spatial extents and timeframes. Well-known examples include mountain-top removal and open-pit diamond mines. Some of these projects are large enough to be seen from space. Oil sands mining is a megaproject with a collective footprint in Canada's western boreal zone that exceeds 813 km$^2$ and is growing (http://go.nature.com/7HE7Zj). Following mine closure, disturbed land must legally be reclaimed under the Conservation and Reclamation Regulation within the Environmental Protection and Enhancement Act[1], which now requires mine companies to return mined lands to a naturally appearing and self-sustaining

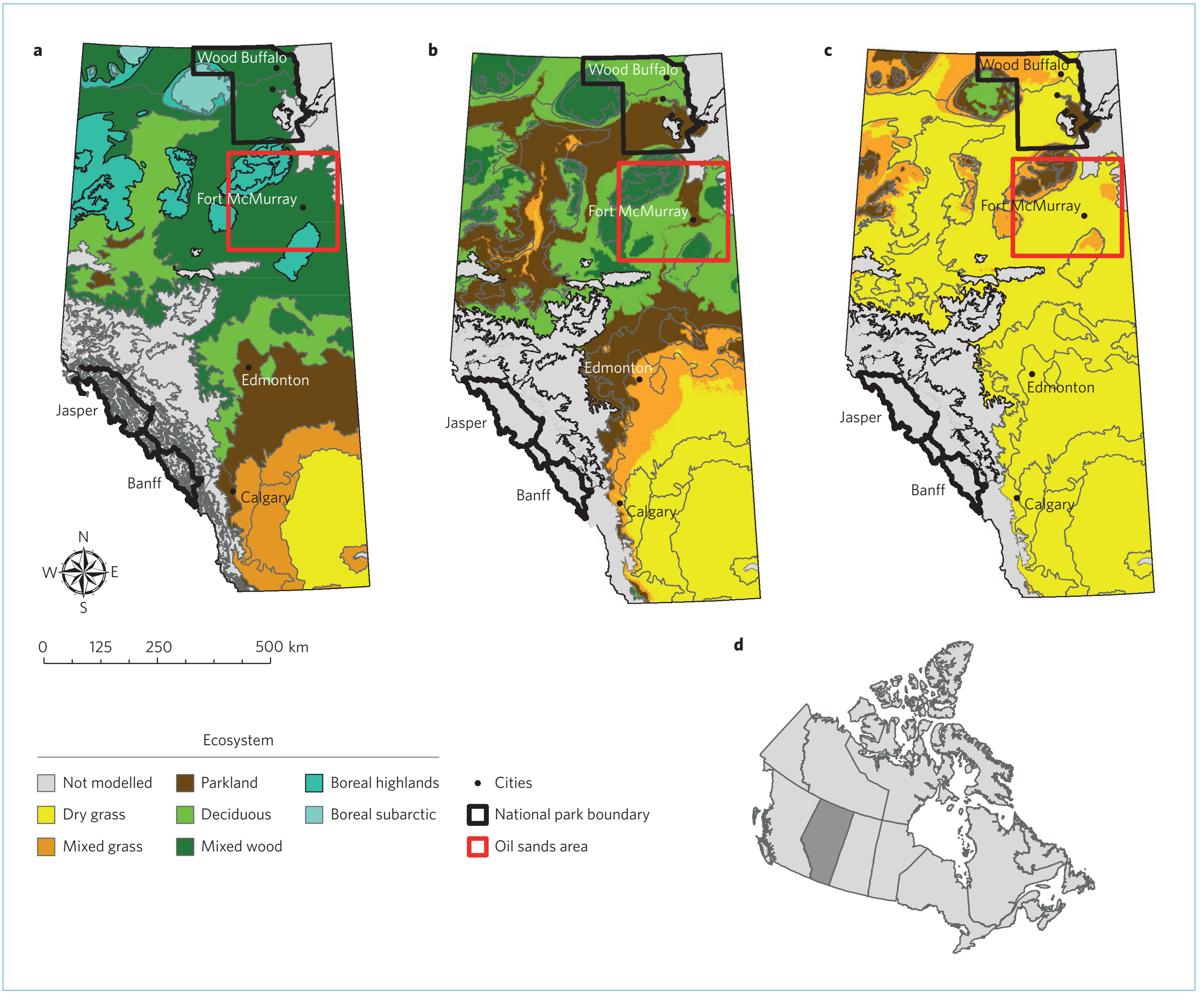


**Figure 1 |** Current and future distribution of ecoregions. **a**–**c**, Distribution of Albertan ecoregions in 2005 (**a**), and the range of predictions for 2080 based on relatively cool (**b**; HADCM3 B1) and hot (**c**; HADGEM A2) projections. **d**, The location of Alberta within Canada. Adapted from ref. 15, ABMI.

state that is integrated with surrounding habitat. Similar regulatory regimes govern reclamation in jurisdictions across North America and beyond (reviewed in ref. 2). But megaproject reclamation is unique in that entire landscapes must be created, consisting of a diversity of upland, lowland and aquatic habitats that are ecologically and hydrologically integrated with each other and with the lands adjacent to the project boundaries[3].

The large amounts of land affected make reclamation a substantial engineering challenge, which is confounded because the timeframes involved must contend with non-stationarity in local, regional and global climate cycles[4]. For oil sands mining, it can take up to 100 years between the initial disturbance and final closure when mine operation and reclamation are taken into account[5]. Such an extensive time lag between disturbance and closure creates a reclamation debt[6] and as such, implementing obligated reclamation processes constitutes a financial liability. With a price tag of Can$10,000–250,000 per ha (ref. 7), reclamation obligations represent a liability of up to Can$15 billion to the industry and the country[8]. Resource extraction megaprojects all face similar concerns because their vast spatiotemporal extents create uncertainty over whether the requisite hydroclimatic conditions will be met for reclamation to succeed. If companies fail to produce naturally appearing, self-sustaining and integrated landscapes, the cost of clean up and reclamation would be in the billions, and likely the public would need to pay it.

The environmental concerns surrounding oil sands reclamation are extensive and analogous to those faced by many megaprojects, but given the current deficit issues in Alberta (projected at Can$5 billion in 2015; ref. 9), criticism of the province's fiscal management of the oil sands reclamation liability[8], and recent volatility in crude prices, the issue of the success of oil sands mine reclamation has never been more relevant from an economic and policy perspective. Consequently, we use Canadian oil sands mining as a case study to illustrate what we see as a major concern in reclamation planning and the regulation of megaprojects.

## Changing climate

Most reclamation and closure plans are designed with an assumption of stationarity in the relationships between the abiotic environment, hydrology and climate variables; under a changing climate, however, this assumption is no longer valid[4]. Even with tens of thousands of hectares of land requiring reclamation and the long timeframes involved, the potential for ongoing climate change to affect reclamation is typically ignored by regulators and industry. In addition, non-stationarity in climatic conditions and climate change has been largely neglected by scientists studying reclamation, although there are exceptions[7,10]. Interactions between climate and anthropogenic disturbance can have nonlinear effects on ecosystem function or force ecosystems beyond critical thresholds[11], and thus require careful study.

Despite longstanding and widespread acknowledgement that climate change will affect the distribution of species[12], closure plans continue to promise the recovery of disturbed lands through the creation of habitats suited to the pre-disturbance climate. In Alberta, oil sands mining activity takes place in the boreal region (boreal subarctic, mixed wood and some non-modelled regions in Fig. 1a), which currently covers 58% of the province (381,046 km$^2$; ref. 13). Existing mine closure plans propose to put back boreal habitats once mining is finished[6,9,14]. But work by Schneider *et al.*[15], using the IPCC B1 (low emissions; Fig. 1b) and A2 (high emissions; Fig. 1c) marker scenarios in combination with five global circulation models, suggests that by 2080 the boreal region may be extirpated from Alberta.

Much of Alberta's boreal forest exists within the subhumid boreal plains region[11] and stands on the precipice of a tipping point[16], where projected changes in the timing and quantity of precipitation are expected to cause tree-killing droughts[17]. Threats to the boreal forest are severe because the direct effect of changes in precipitation and temperature will be compounded by indirect effects of climate change, including altered fire regimes[18] and an increased risk of pest outbreaks[19]. Although uncertainty remains in predicting how natural communities will respond to these changes by dispersal and adaptation[20], attempts to create reclaimed boreal landscapes based on the biological assemblages typical of historic climate norms are unlikely to succeed over the long term[21].

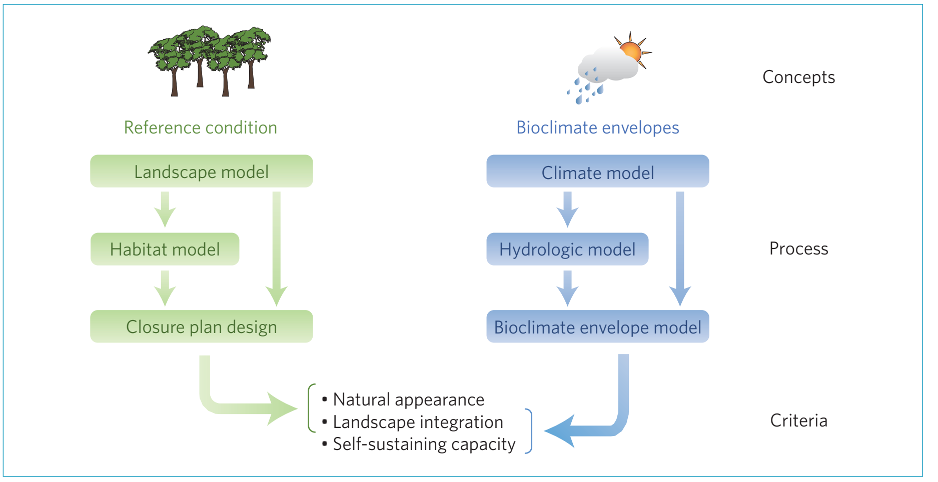


**Figure 2 |** Megaproject reclamation and climate change. Conceptual framework for meeting megaproject reclamation criteria by integrating the concepts of the bioclimate envelope and the reference condition at multiple spatial scales.

Notwithstanding the role of dispersal abilities, biological interactions and evolutionary change[20], projected climate change will certainly influence ecohydrological regimes and affect what species assemblages may constitute reclamation targets capable of sustaining themselves over the next century. We contend that to be sustainable, rather than targeting static ecosystems with historical fidelity, reclamation projects must aim to create ecosystems capable of adapting in step with the changing climate.

## Framework for reclamation success

The framework that we propose for improving the success of megaproject reclamation combines two concepts: the reference condition applied at local and landscape levels, and the bioclimate envelope (Fig. 2).

**The reference condition.** The reference condition approach originates from the field of ecosystem assessment[22]. Its premise is simple: to evaluate the degree of impairment suffered by a disturbed ecosystem, one should compare it with a platonic ideal — the 'reference condition' — of how that ecosystem would look and behave in the absence of disturbance. We have already harnessed the reference condition approach to set reclamation targets for individual habitat patches that mimic natural habitats in form and function[23]. Here we propose that the technique be adapted to megaproject reclamation by characterizing the composition (proportional amount) and configuration (spatial arrangement) of different habitat types in reference landscapes and then using these aggregate landscape properties as targets in megaproject closure plans. We identified 14 independent landscape metrics that can be mirrored in closure plan designs to improve the resemblance of reclaimed landscapes to natural ones: total area; number of patches; largest patch index; total edge; edge density; mean patch area; mean patch shape; mean of the perimeter to area ratio for patches in a class; perimeter to area fractal dimension; mean Euclidean nearest neighbour; contagion; patch richness; patch richness density; and cohesion. Implementing the reference condition approach at habitat patch and landscape scales will help to meet regulatory requirements that reclaimed landscapes be natural in appearance and integrate with surrounding lands (Fig. 2), as it involves targeting naturally occurring habitats in spatial arrangements that reflect the natural variability in environmental and biotic conditions at local and landscape levels.

**Bioclimate envelope models.** We propose that designers working on megaproject reclamation and closure plans integrate future climate projections by applying bioclimate envelope modelling[15], wherein associations between climate, hydrology, species occurrences and water-use efficiency are used to map the distribution of biotic assemblages as a function of climate. This approach is effective because hydrology and water-use efficiency mediate the relationship between vegetation and climate. Therefore, by integrating climate and hydrologic projections we can predict what vegetation assemblages should be capable of persisting in a given location.

Bioclimate envelope modelling involves screening physical and climate variables, identifying variables that represent dominant trends in the distribution of biota, clustering to construct environmental strata, and aggregating strata into ecological zones[24]. By using projected climate and hydrologic values to identify the trajectory of change from one ecological zone to another in a given location, the appropriate reference conditions can be identified to ensure sustainable reclamation in the face of climate change (Fig. 2).

Bioclimate envelope models have been criticized[20]; when used appropriately, however, they can provide valuable information for conservation[25]. Many of the uncertainties regarding the adaptation of natural communities to climate change are overcome by applying bioclimate envelope models to the design of megaproject reclamation, because reclamation following megaprojects begins with a *tabula rasa*: everything from the topography and soils through to the biology must be assembled from scratch. Thus, concerns regarding differential dispersal rates and the creation of 'no-analogue' communities[26] can be overcome by ecosystem engineering and the use of propagule prescriptions to achieve target communities based on a climate-suitable reference condition.

The process that we recommend for integrating climate projections with the reference condition approach to reclamation at local and landscape scales involves six steps: three to set reclamation targets capable of adapting to the changing climate and three to ensure that targets at the habitat patch and landscape levels resemble natural analogues (Fig. 2).

(1) Climate model: Identify potential future regional climate envelope with multiple scenarios and models to capture uncertainty.
(2) Hydrological model: Estimate impact of climate pathway variables on hydrologic processes to establish the water budget for reclamation.
(3) Bioclimate classification: Combine climate variables from (1) (for example timing of snow melt, length of growing period) and hydrologic variables from (2) (for example precipitation to potential evapotranspiration ratio, run-off yield) in the bioclimate classification approach[23] to identify reclamation targets that would be self-sustaining and capable of integration with adjoining land.
(4) Landscape model: Locate low-disturbance regions currently within that climate envelope possessing similar geomorphology and soils to the mined area, and characterize their habitat composition and configuration as reference landscapes.
(5) Habitat model: Characterize the biotic and abiotic conditions of habitats or ecosites within reference landscapes to define patch-level targets.
(6) Closure plan design: Integrate climate-appropriate habitat patches in a configuration characteristic of reference landscapes to produce climate-appropriate reclamation targets, at the landscape level, that will have a natural appearance and be self-sustaining within the constraints of the water budget.

If adopted, this process should provide a scientifically sound approach to setting reclamation targets that will not only be natural-looking and integrate with surrounding lands, but will be self-sustaining under future climate conditions.

## Research needs

We propose that reclamation targets and design criteria be guided by characterizing appropriate natural landscapes and habitats in terms of their climate, hydrology, soil and water chemistry, and biological form and function using a reference condition approach (see Bailey *et al.*[22]) that will meet the criteria of being naturally appearing and self-sustaining. To achieve this, we must address several research gaps. First, we must integrate hydrological processes and bioclimate envelope models better, to embrace an ecohydrological approach to reclamation targeting, particularly in regions such as the western boreal where climate change is likely to tip the balance on the water budget[17]. Second, we must characterize reference conditions in terms of the composition of biological and environmental properties as well as their configuration at the landscape scale.

We argue that neglecting climate projections when setting targets for reclamation puts the sustainability and resilience of reclaimed lands at risk, presenting a major environmental and economic liability. Reclamation efforts, policy certifying reclamation closure, and the scientific research guiding both processes need to incorporate climate uncertainty from the design to the evaluation phase of reclamation to ensure that reclaimed lands possess resilience in the face of climate instability. Our proposed framework incorporates an uncertain climate future into reclamation plans to maximize the potential long-term sustainability of reclamation and limit the risk of failure for large-scale megaprojects. ❐

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