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# Synergies and trade-offs between adaptation, mitigation and development

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**Abstract** To succeed in meeting carbon emissions reduction targets to limit projected climate change impacts, it is imperative that improved synergies be developed between mitigation and adaptation strategies. This is especially important in development policy among remote indigenous communities, where demands for development have often not been accompanied by commensurate efforts to respond to future climate change impacts. Here we explore how mitigation and adaptation pathways can be combined to transform rural indigenous communities toward sustainability. Case studies from communities in Alaska and Nepal are introduced to illustrate current and potential synergies and trade-offs and how these might be harnessed to maximize beneficial outcomes. The adaptation pathways approach and a framework for transformational adaptation are proposed to unpack these issues and develop understanding of how positive transformational change can be supported.

## 1 Introduction

Adaptation to climate change is a significant issue currently facing many communities around the world, particularly indigenous and rural communities in developing countries. Mitigation by contrast is considered mostly at larger scales and rarely at the local level. While climate change mitigation can be conceptualised as a proactive set of concrete actions to lessen anthropogenic greenhouse gas emissions, adaptation to climate change is best perceived as a set of processes unfolding in response to a host of social and environmental forces operating over local, regional, national, international and planetary scales (Thornton and Manasfi 2010). Unlike mitigation measures, adaptation pathways are neither inherently progressive nor necessarily directed towards a singular end. Ideally mitigation can *synergise* with adaptation to climate change, if for example human communities successfully limit

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consumption and pollution such that anthropogenic climate impacts are reduced and social-ecological conditions for wellbeing are rendered more sustainable and resilient for future generations. As the Fourth Intergovernmental Panel on Climate Change assessment report (IPCC 2007a) states, although macro-economic policy, agricultural policy, development bank lending, energy security, forest conservation and other such subject areas, are rarely considered alongside climate policy, decisions made in these areas can significantly reduce emissions; and conversely "non-climate policies can affect adaptive capacity and vulnerability" (IPCC 2007a: 61). Exploiting the benefits of mitigation-adaptation synergies in the energy, forestry, and agricultural sectors is important to sustainability and so-called "green growth" (Corfee-Morlot and Agrawala 2004; IPCC 2007b; UNEP 2011), and especially for indigenous and local communities that tend to interact closely with and depend heavily upon their local natural environments (Gadgil et al. 1993). Thus, it is on these sectors of indigenous social-ecological systems that we focus in this paper.

Humans are inherently adaptable, generally responding to environmental and social conditions according to the opportunities, costs and benefits posed by pathways available to them when change occurs. Such adaptive responses to environmental or other change are often autonomous, incremental and heterogeneous within communities. Pathways pursued by individuals or groups in response to changing conditions may involve adapting systems of knowledge, values, behavior, organization, and material technology to support continued wellbeing. These adaptive responses, often initially reactive and opportunistic, are rarely planned and may not align with development or mitigation strategies. This can lead to what we term the *mitigation-adaptation disconnect*, where proactive mitigation policies at one level fail to connect or synergise with adaptation processes at another, and may even work at cross-purposes to planned or autonomous processes of adaptation that are working at other levels and scales (IPCC 2007b; Dang et al. 2003; Thornton and Manasfi 2010).

We argue that mitigation and adaptation in many cases can only be effectively synergised when this disconnect is addressed under a common rubric of social-ecological transformation. This perspective recognizes that in situations where the impacts of climate change are particularly extreme or rapid, and where populations are especially exposed or vulnerable to these impacts, incremental, autonomous adaptation may be insufficient. In such cases, a more radical adaptive response, *transformational adaptation*, referring to fundamental changes to a social-ecological system (Olsson et al. 2006), may be required (Kates et al. 2012). Additionally, with international efforts to mitigate the impacts of climate change falling short of what is needed, and anticipated impacts increasing in severity and magnitude (New et al. 2011), successful attempts at mitigation may require not merely alterations in social behaviour and energy systems, but fundamental, transformative changes to cognitive, social and material systems to create significant reductions in the global environmental impact of human societies.

An increasingly common discourse asserts that the adaptive capacity, or the overall potential of a system to respond to change (Levine et al. 2011) of human communities can be increased by development interventions (Huq and Reid 2009; Lemos et al. 2007). Yet, while such interventions may increase the potential for incremental adaptation along pathways already realized (e.g. intensification or diversification), commonly realised development interventions often do not support more radical, transformational adaptation. Furthermore, where mitigation strategies require transformative changes in lifestyles, dominant developmental strategies may conflict with the required direction of change. The Green Growth (OECD 2012) and planetary boundaries (Rockström et al. 2009a, b; Raworth 2012) initiatives emerging from the United Nations Conference on Sustainable Development offer some direction for reconnecting the mitigation-adaptation disconnect, but do not necessarily recognise the range of human adaptation pathways and modes of transformation available or already being pursued autonomously by many indigenous peoples in diverse social-ecological contexts.

This paper develops adaptation and transformation theory among indigenous communities, often the most environmentally exposed, marginalised, and resource dependent groups on the front lines of environmental change and sustainability challenges (Gadgil et al. 1993; Smith et al. 2003; Nakashima et al. 2012). We argue that adaptation and development planning that considers both the full range of adaptation pathways and critical processes of transformational adaptation offers the best opportunities for achieving synergies between adaptation, mitigation and development.

Two case studies are presented to illustrate this two-pronged approach. Indigenous communities faced with rapid climate change in a Himalayan region of Nepal are compared to indigenous communities in Alaska seeking to transform their energy systems to provide multiple adaptive and global mitigation benefits. Together these cases illustrate the practical application of the theory of transformability in linking adaptation, mitigation and development strategies and interventions among indigenous communities.

## 2 Adaptation pathways and transformational change

Thornton and Manasfi (2010) suggest that adaptation to climate change is best conceived of as a set of processes that can follow at least eight major pathways. They offer a metalanguage for recognising and assessing adaptation processes, including 1) mobility, 2) rationing, 3) exchange, 4) pooling, 5) diversification, 6) intensification, 7) innovation, and 8) revitalisation.[1] These pathways may overlap, intersect, and synergise or conflict in the context of climate change (and other) processes, events, and interventions.

Development interventions impacting indigenous and rural communities worldwide can either support or undermine existing adaptation pathways, or both. Often development is predicated on a limited set of adaptation processes, specifically diversification (or substitution) and innovation, whereby a new livelihood or technology is directly supported as part of a development project to reduce poverty or vulnerability, or improve socio-technical capacity for natural resource exploitation or management. Such support can improve adaptation along these particular pathways, but at the same time may ignore or even undermine other adaptation alternatives or institutions, thus potentially reducing overall adaptive capacity.

In contrast, participatory or bottom-up development can support autonomous responses to environmental change in line with current activities or processes. Such autonomous responses may be termed '*incremental adaptation,*' distinguishing it from more fundamental or radical change, increasingly termed '*transformational change*' (Kates et al. 2012). Transformational change involves fundamental changes to key processes within a social-ecological system in response to shocks or other stimuli (Walker et al. 2004; Folke et al. 2005, 2010; Olsson et al. 2006), and capacity to respond in such a way can be referred to as 'transformability'(Folke et al. 2010). Transformability thus differs from *resilience*, a system's ability to cope with or absorb shocks while retaining basic structure and function (Folke et al. 2005), as it involves fundamental alterations to system functions. Conceived of

[1] Adaptation is defined here as the ability for human groups to successfully adjust to actual or expected environmental changes (especially climate change impacts) and their effects; whether it be incremental or transformational. Further, adaptation can be autonomous or planned, and the scale of the stimulus is likely to affect both autonomous responses and recommended adaptation measures (Smith et al. 2000). Resilience is defined as a social-ecological system's ability to absorb, reorganize to cope with or benefit from disturbances, while retaining its basic structure, function and feedbacks (Folke et al. 2005; IPCC 2007a).

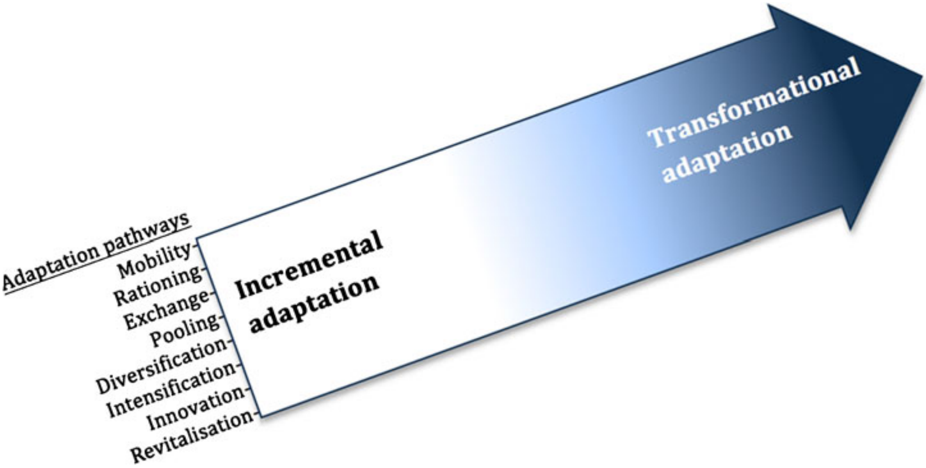


**Fig. 1** Adaptation pathways for incremental and transformational change

here, transformational adaptation need not be isolated from other forms and pathways of adaptation, or adaptive capacity, but is most usefully conceptualised as the radical end of more conventional adaptation processes and capacities (see Fig. 1 for an illustration of this).

Where human communities are exposed to rapid climate change, or are particularly vulnerable to its impacts, incremental adaptation may be insufficient (Kates et al. 2012). This is expected particularly in communities with high dependency upon limited natural resources or ecosystem services, and in regions affected by extreme environmental change; categories that often apply to marginalised or underdeveloped indigenous and rural communities worldwide (Kates 2000; Smith et al. 2003; Nakashima et al. 2012). In such situations, transformational adaptation may be necessary or inevitable (Kates et al. 2012) whether positive transformation to a more advantageous, secure state, or negative transformation to a less desirable state of increased vulnerability (Chapin et al. 2009). Thinking beyond incremental adaptation to transformational change is especially relevant when considering adaptation, mitigation and development strategies among indigenous communities.

In the next section, we outline a framework for assessing the key factors relevant in supporting transformational adaptation in indigenous communities.

## 2.1 Framework for transformational adaptation in indigenous and rural communities

To advance understanding of the factors necessary for transformational change within rural and indigenous communities, and inform its support, a framework is proposed (see Fig. 2). Based upon existing literature on transformational change (e.g. Olsson et al. 2006), and social change (e.g. Reed et al. 2010), the framework was developed using investigative research in the Himalayan communities of Humla, Nepal, to ensure applicability for transformational adaptation within indigenous communities. The elements perceived to be relevant in allowing transformational change to occur are described below.

1. Transformation can be triggered by a **Window of Opportunity**, such as rapid change, ecological crises (Folke et al. 2005), or social and economic shocks (Olsson et al. 2006). Windows triggering transformations may differ between regions and populations,

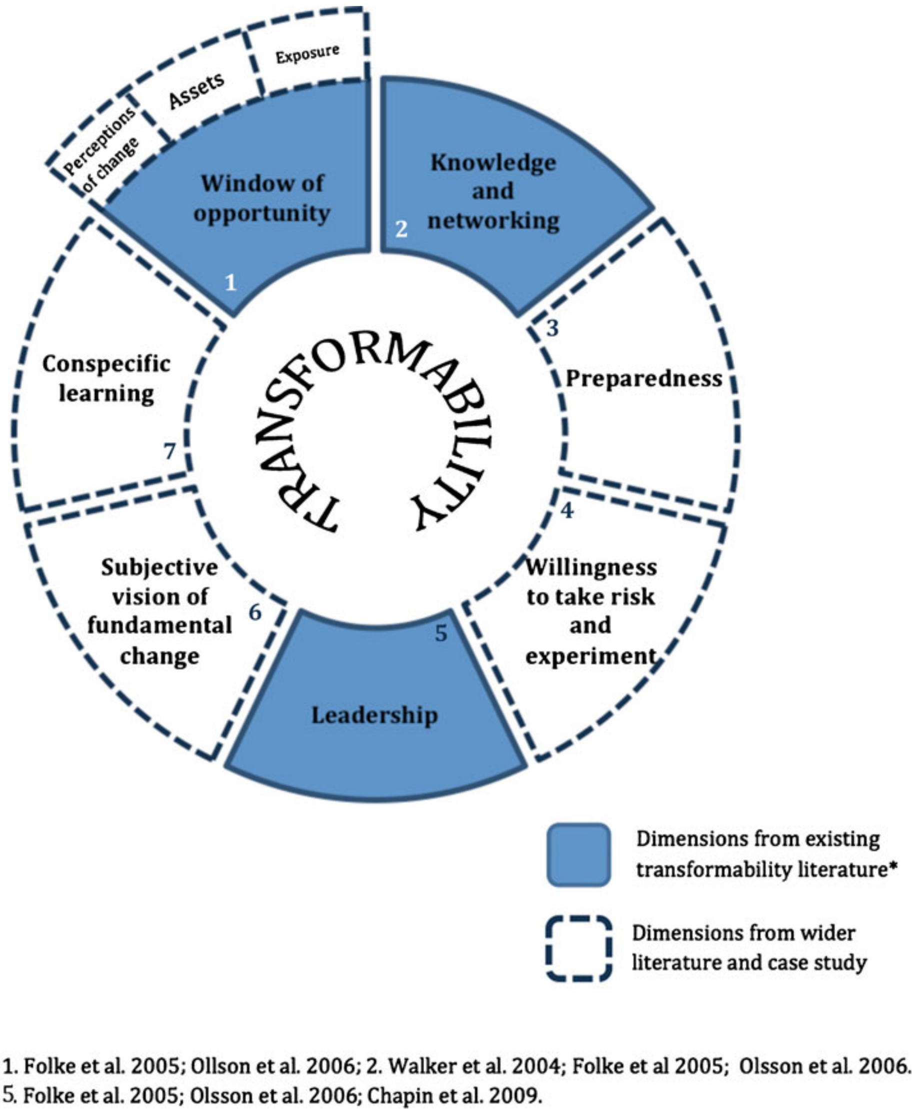


**Fig. 2** A framework for transformational adaptation within indigenous and rural communities in response to environmental change

determined by *exposure* (Adger 2006); *assets* present, which determine opportunities for adaptive responses (Levine et al. 2011); and subjective *perceptions of change* occurring (Beratan 2007), which affect behavioural responses.

2. **Knowledge**, and ability to make informed choices, is a key feature of adaptive capacity (Levine et al. 2011), and can determine whether adaptive transformations occur (Mimura et al. 2007; Ensor 2011). Traditional knowledge, a wellspring of learning informing adaptation among rooted indigenous and local communities, evolves through adaptive processes across generations of engagement with particular landscapes. Traditional knowledge systems are critical to producing flows of information while social

**networks** distribute and assess them and thus facilitate the uptake of new information as credible and potentially transformative knowledge. Information translated through the lens of a particular social context or traditional knowledge system may be more transformative than science-based knowledge because of its embeddedness in social-ecological systems of practice (Beratan 2007).

3. **Preparedness**, the presence of plans or ideas for coping with potential future shocks or perturbations, can facilitate transformability (Olsson et al. 2006), highlighting the anticipatory aspect of transformational adaptation (Kates et al. 2012). Traditional knowledge systems, often transmitting experiences of past environmental changes within social memories (Ford and Smit 2004; Reidlinger and Berkes 2001), may be critical to the maintenance of preparedness and alternative strategies over time. Preparedness is critical to what the IPCC has termed "anticipatory adaptation," wherein human response strategies are implemented before the brunt of environmental impacts or stresses are felt.
4. **Willingness to experiment and take risk** is important due to the high magnitude of change and thus uncertainty of both outcomes and triggers of transformational change (Chapin et al. 2009). Risks are inherent with uncertainty, and perceptions of and attitudes towards risk may thus impact transformability (Walker et al. 2004).
5. **Leadership** can initiate and guide transformation (Olsson et al. 2006; Folke et al. 2005) towards adaptive social change (e.g. Wallace 1956) by developing and communicating visions, legitimating and valorising new patterns of thought, behaviour and organisation, and mobilising support for changes in sociocultural systems.
6. Definitions of transformations as changes to the *essential functions* of a system (Walker et al. 2004; Folke et al. 2005, 2010; Olsson et al. 2006) may be insufficiently objective. A locally relevant, **subjective vision of fundamental change** should be considered, with traditional knowledge, customs and beliefs central to shaping and sanctifying this vision.
7. C**onspecific learning**, or learning from others we consider 'like ourselves', is the final factor in our model of transformational adaptation. Distinct from social learning (see Berkes 2008; Reed et al. 2010) conspecific learning does not require widespread social uptake for transformations to occur. Further it considers how agents of change are viewed. A common problem in development in indigenous communities is that the agents of change, often outside specialists and interlopers, are viewed as unlike the people themselves, making it harder for locals to imagine themselves transforming according to pathways prescribed by these alien agents.

## 3 Synergies and trade-offs between transformational adaptation, mitigation and development in Humla, Nepal

Humla, one of the most isolated and least developed regions of Nepal, is located in the far north-west of the country, borders Tibetan China and encompasses a small section of the western Nepal Himalayas. Ranked 68th out of Nepal's 75 regions in terms of Human Development, and 75th in Human Poverty (UNDP 2004), the region is home to approximately 40,000 inhabitants, mostly of Tibeto-Burman descent ('Bhotiya' or 'Lama'), or indigenous Nepali castes (Chhetri and Takuri).

Despite just 1 % of the region's land being cultivable (Bishop 1990), rain-fed agriculture is the mainstay of the region's economy (Shrestha 2009), and a prevalence of traditional nonmechanised farming practices make the region's food security heavily vulnerable to climatic variability–specifically rainfall. The region has long suffered chronic food shortages (Adhikari 2008), and food aid provides critical support in times of scarcity. A high dependence upon natural resources, including collection of wood, medicinal and aromatic herbs, and fodder for livestock is commonplace and contributes up to 50 % of household income (Olsen and Larsen 2003). Significantly, these resources are being over-exploited (ADB 2010), and deforestation is a widely acknowledged problem in the Humla region (DDC 2008).

The region is extremely vulnerable to climate change. Rainfall is increasingly unpredictable (Shrestha and Devkota 2010) and generally declining (Gurung et al. 2010), and warming rates in the Himalayas are among the fastest on Earth (Leduc et al. 2008). Impacts on agricultural production and thus livelihoods are already significant (Karki and Gurung 2012). Given this high exposure, low levels of development and high dependence upon natural resources, Humla communities are cases in which incremental, autonomous responses may not be sufficient to prevent loss of adaptive capacity; instead transformational adaptation may be necessary.

Fieldwork conducted in five villages in Humla, Nepal, between June and July 2012, explored this hypothesis. Findings indicate that climate change is heavily impacting the livelihoods of villagers, with 80 % reporting diminished crop production and thus food availability, mostly attributed to reductions in rainfall. Individuals are turning to other means to generate cash and purchase food to fill the gap, with 62 % of households interviewed undertaking new livelihoods activities in recent years, most citing declining crop production as the cause. Some seek paid labour such as portering and road construction, but more than 60 % of cases involved collection of herbs and wood to sell. Deforestation is a significant issue in the region, and was clearly evident.

A negative feedback emerges, with climate change-induced food shortages leading to over-harvest of increasingly scarce natural resources, threatening future capacity to respond to climate change and, through local effects of deforestation, further threatening future crop yields. Incremental adaptation to climate change is increasing future vulnerability, and transformational adaptation is necessary.

Cases of emergent transformation in Humla were identified and analysed, allowing the framework to be refined. One example considers the death of one household's sheep herd 4 months prior to interview, reportedly due to a lack of rainfall which inhibited growth of grasses for fodder. The family decided not to replace the sheep but invest instead in opening a shop. The decision stemmed from a perceived continuous decline in annual rainfall over preceding years and subsequent worries about the continued viability of herding to support the family in such conditions. The idea reportedly arose through the son's observations of shopkeepers in Taklakot, the nearest trading centre in Tibetan China, 3 days walk away. The son, along with many men of the region, had begun making the journey increasingly frequently to purchase foodstuffs and alcohol to re-sell locally for profit. During these visits he noted significant incomes achieved by the Taklakot shopkeepers and so decided to attempt the same.

A second case of transformational adaptation involves a husband and wife who 5 years previously had opened one of the first hotels in their village. The idea arose after visiting the regional capital Simikot for a development-funded training session where they witnessed successful hotel businesses first-hand and perceived a potential opportunity. A final case involves a schoolteacher and farmer who, upon funds being made available by a local development organization, opened a tea shop. Both explained that the decision was in direct response to 5 or 6 years of poor crop yield, perceived to result from reduced rainfall, resulting in insufficient food and increasing uncertainty in future provisioning for their family. Each case involved changes to livelihoods that were deemed transformational, and highlight key elements of the framework (Fig. 2) significant in supporting these changes.

Across the three cases a *window of opportunity* was significant in initiating transformation, with sudden loss of livestock, increasing and repeated exposure to food insecurity, and availability of funds all acting as triggers, with *exposure* (to climatic variation), *assets* (making transformative change possible) and *perceptions of change* all critical factors. Recognition of a progressively changing climate was a crucial trigger. Transformations were apparently driven by climate change, although a scientific understanding was largely irrelevant since in only one case–that of the teacher–was the phenomenon of climate change manifestly recognised or understood.

*Willingness to experiment or take risks* was crucial, with the risk of undertaking a novel activity acknowledged in every case. An attachment to traditional livelihoods had to be overcome, often with clear regret that traditionally secure occupations were no longer viable.

Although relevant in many cases of social change, *leadership* here was not significant. Social *networks* did prove influential, however, with the hotel owner and teashop owner admitting that they drew encouragement from peers undertaking similar ventures. More relevant, it seems, was the opportunity to directly observe others like themselves successfully undertaking a novel and replicable livelihood: the shepherd observed the shopkeepers of Taklakot, the hoteliers witnessed successful hotels, and the teashop owner received advice from peers in similar occupations in Simikot. *Conspecific learning* thus emerged as critical in initiating transformation.

These transformations all constitute *diversification*, and this adaptation pathway was the most commonly observed in the region. As most other diversification responses witnessed in Humla involved increased dependence on forest products, an important adaptation-mitigation trade-off is highlighted: incremental adaptation is diminishing forest stock, and continuing climate change along current trends will undermine attempts to mitigate climate change impacts through protection of local forests.

Transformational adaptation offers a potential route out of this destructive cycle. By transforming adaptive responses towards non-environmentally destructive activities, deforestation can be reduced. Transformational adaptation thus can act to synergise adaptation and mitigation processes.

Developmental interventions may also offer synergisms, with planned interventions such as road building to increase access to the region potentially increasing opportunity for transformation. Yet in any intervention, the importance of traditional knowledge in a community's ability to undergo significant changes (Macchi et al. 2008) must be recognised, and forcing change without adequate support or recognition of traditional knowledge systems and practices can undermine the adaptive capacity of communities (Fabricius et al. 2007).

Development trade-offs are likely. Development can increase demand of local populations and lead to rapid environmental degradation, potentially increasing vulnerability and undermining adaptive capacity (Norberg-Hodge 2009), and can increase dependence upon cash income and augment rates of deforestation.

The synergies and trade-offs between adaptation, mitigation and development are complex and contingent, requiring detailed knowledge of local social-ecological contexts and adaptation and transformational processes to harness synergies. In the case of Humla, development interventions should consider the possible impacts on adaptive strategies and climate change mitigation to ensure the nexus between them results in positive outcomes for human wellbeing.

## 4 Transformational adaptation and renewable energy in Alaska Native communities

With the discovery of the North America's largest oil field on the north slope of Alaska in 1968, Alaska's economy and Native communities were irreversibly transformed. The state population doubled in just 30 years from just 300,000 in 1970 to more than 625,000 in 2000 (US Census

2000). Aboriginal land and resource rights were extinguished by the accompanying Alaska Native Claims Settlement Act (ANCSA 1971), which organized the state's Aleuts, Alutiiq, Yup'ik and Inupiaq Eskimo, Athapascan, and Tlingit and Haida Indians into village and regional business corporations to manage a settlement of 44 million acres of land (about 10 % of the state) and $962 million dollars in compensation (about $3 per acre) for lands taken. A pipeline was built to link the North Slope oil fields to a deep-water, ice-free port at Valdez, nearly 1,000 miles south. Alaska became an oil state, with production and associated activities providing more than 80 % of state revenues and contributing to significant rural development (Haycox 2002). Today, as oil prices soar and supplies dwindle, investment in many areas of rural Alaska has declined, and outmigration among indigenous village dwellers to regional and urban centres is rising rapidly in many areas (Sikka et al. 2013).

This crisis is compounded by the direct effects of climate change which include rising sea levels, loss of sea ice for travel and shoreline erosion protection, more severe storms, permafrost damage, and invasive flora and fauna, which threaten arctic communities and traditional livelihoods. In 2008, the city and Native village (federally recognized Inupiat tribe) of Kivilina went so far as to sue Exxon Mobil Corporation and 23 other fossil fuel and power companies in the US federal court, claiming the companies' copious greenhouse gas emissions and efforts to undermine climate change science and policy threatened their existence (the case ultimately was dismissed for lack of jurisdiction and standing; see Kivalina v. Exxon et al. 2012). Ironically, arctic states' main hopes for increasing rural development and energy security centre on accessing new hydrocarbon energy supplies by drilling in arctic waters off shore of Alaska, Canada, Greenland, Fennoscandia, and Russia (Schiermeier 2012). This is symptomatic of the mitigation-adaptation disconnect, as such an *intensification* response maladaptively counters efforts to mitigate climate change impacts by reducing global greenhouse gas emissions generated by reliance on fossil fuels.

In contrast, the current crisis in many northern communities, triggered in part by recent fossil fuel energy price spikes, has many Alaska Native communities and corporations urgently searching for alternative, renewable and local sources of energy. This search provides a *window of opportunity* for potential mitigation-adaptation synergies to address climate change and sustainable rural development. Major potential exists for biomass, geothermal, hydro, tidal, and wind energy, yet transformation costs are high (Johnson et al. 2012). Small hydro, biomass and wind energy projects have been successfully installed but typically only when catalysed by significant outside investment. Hence the conditions for rural energy transformation remain subject to high uncertainty and risk. Nevertheless, the potential triple bottom line of benefits through 1) environment-friendly mitigation of greenhouse gas emissions from fossil fuels; 2) economic payoffs through cheaper, more sustainable energy sources; and 3) social dividends through increased local jobs in the energy sector and reduced costs of rural living has mobilized indigenous peoples to call for increased investment in alternative energy. In 2009, 85 Alaska Native and other villages in remote areas of the state came together to support a resolution for a federal renewable electricity standard and other policy tools for transforming their energy sectors away from oil dependency (UCUSA 2009).

In some remote tundra communities wind power has proven viable, and these Alaska Native groups are investing in this transformative technology. A consortium of four Native villages in Southwest Alaska, the Chaninik Wind Group, recently installed a state of the art system in the Yup'ik village of Tuntutuliak, combining wind power with smart-grid technology and residential electric thermal storage to optimize wind generation for electricity and heating needs. Nearby villages at Kongiganak and Kwigillingok are in line to follow (AFN 2012). A larger scale initiative, Banner Wind Farm, was launched by two Alaska Native corporations near the city of Nome to produce 900–1,170 kW of power via 18 wind generators, supplying about 10 %

of electricity needs. Revenues from the venture are to be shared between Sitnasuak Native Corporation (SNC) and Bering Straits Native Corporation (BSNC), with a plan to reinvest 50 % of profits toward renewable energy projects in more remote villages in Northwest Alaska. Such renewable energy projects will reduce the dependency on oil (which must be barged or flown in), lower greenhouse gas emissions, and create monetary and employment dividends for rural shareholders of the Native corporations. Native shareholders are being trained for employment in the sector, carrying out energy audits and retrofits, and installing and maintaining equipment (Deanna Kingston, pers. comm. 2010). While the project has yet to meet its potential due to "design and operational problems" (Sitnasuak Native Corporation 2012) and lack of energy storage capacity (batteries) to synergize renewables with diesel, it may yet prove transformative for the region's energy system.

Among the most promising sources of renewable energy in the subarctic boreal and temperate rainforests are biofuel stocks from trees and forest residue.

Indeed, before petroleum, wood biomass energy was the most common source of energy in human societies, and remains critical to the world's indigenous peoples, especially in marginal areas not served by power plants (MacQueen and Korhaliller 2011). The IPCC (2007a, b) suggests: "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre, or energy from the forest, will generate the largest sustained mitigation benefit." In many indigenous forest communities these strategies already exist, based on traditional knowledge and practices evolved over generations to provide heat and metabolic energy. When combined with new knowledge and socio-technical development, such strategies can lead to adaptive transformation towards sustainable energy systems needed for contemporary livelihoods and wellbeing.

In Alaska, forest residue from small-scale and commercial timber operations generally lies unused, eventually decaying and emitting $CO_2$ into the atmosphere. Using wood residues to displace oil heat capitalizes on this residue, while reducing greenhouse gas emissions through avoided burning of fossil fuels. Yet adapting land use to take advantage of forest residue requires transformation of the timber and heating fuel sectors in indigenous communities. If managed poorly, emissions associated with direct and indirect land use change alone may negate climatic benefits of biofuels, as feedstock cultivation may supplant carbon-rich ecosystems and associated ecosystem services. This, in turn, can have deleterious implications for rural livelihoods and traditional land uses that depend on existing biomass (German et al. 2011).

Sealaska, the regional Native corporation for Southeast Alaska's Tlingit, Haida, and Tsimshian peoples, is spearheading transformation toward biomass energy through investment in wood pellet furnace technology and biofuel production. The company created a subsidiary, Haa Aaní ("Our Land") LLC in 2009, designed to promote sustainable development in rural shareholder communities with renewable energy as a strategic focus. This investment strategy constitutes a *window of opportunity* for transformative change in energy provisioning (Haa Aaní 2012).

Haa Aaní LLC chose to stimulate learning and interest in biofuels by transforming its own 50,000 square foot headquarters to a wood-pellet based heating system. This $539,000 demonstration project shows clear benefits to converting to biomass energy, with the company recording savings of $16,137 over oil based heating in 6 months of operation. Haa Aaní LLC is now seeking to develop a regional wood-pellet industry through partnerships and capacity building to produce wood-pellets from local biomass residue associated with Sealaska's timber operations. The *Southeast Alaska Integrated Resource Plan* (Black and Veatch 2011) estimates that 80 % of heating oil could be displaced with local biomass energy in 10 years, reducing CO2 emissions by 264,396 tonnes. With a young growth timber base of approximately 500,000 acres in the Tongass National Forest and other available lands, the harvest rate would be sustainable at less than 1 % of the timber base per year.

Thus, if prudently developed, biomass energy has the potential to deliver sustainable economic, environmental and social benefits. Other villages and Native corporations dependent on expensive diesel power plants are following Sealaska's lead (Sikka et al. 2013).

These transformational adaptations are being led by indigenous peoples envisioning a "triple bottom line" of environmental, economic, and social benefits. They are seeking to revitalize the quality of life their rural shareholders have enjoyed for generations in their ancestral homelands, while pursuing sustainable development for their descendants. By adapting as energy producers and consumers Alaska Natives can retain their rural livelihoods, including a rich hunting and fishing economy, the wellspring of their traditional knowledge and culture. While the harnessing of wind power constitutes a major *innovation* in terms of adaptation pathways, the capture of biomass energy involves *revitalization* of a previous keystone energy resource—woody plants—in combination with strategic *intensification* and *diversification* of wood production strategies and *innovation* of efficient biomass energy technologies (via *exchange*). Both the biomass and wind energy cases also require *pooling* and *exchange* of resources to make the transition to renewable energy viable and sustainable at community and regional scales.

High oil prices provided the impetus or *window of opportunity* to reassess energy systems and alternative renewable sources. *Knowledge and networking* through bridge organizations, such as the Alaska Federation of Natives, catalysed *conspecific learning* and *visions of fundamental change* in rural energy systems among Native leaders, villages, tribes, and corporations. Financing schemes, such as Alaska's Renewable Energy Grant Fund (REAP 2012), provided low-risk financial capital, another window of opportunity for *experimentation*. Where renewables have been installed in villages the effects can be transformative, lowering costs of living, stemming outmigration, boosting the value of local renewable energy assets, and creating jobs.

However, as the transformational adaptation model suggests, certain conditions must adhere to effect transformational change over incremental change at larger scales. While transformational adaptation at the indigenous village level is proceeding apace in Alaska, the broader energy strategy of the state and nation remains hugely dependent on fossil fuel production, potentially negating greenhouse gas emissions reductions made through the local low-carbon renewable energy conversions. Will local transformational adaptation from indigenous and other low-carbon communities ultimately help to reduce the mitigation-adaptation disconnect at the state and national levels?

## 5 Discussion

Indigenous peoples are disproportionately exposed to climate change impacts due to their marginal homelands and natural resource-dependent livelihoods. Lack of political influence, land rights and limited territories and resources further contribute to their vulnerability to climate change stressors. Yet, indigenous peoples and remote communities in both developed countries, like the US, and developing countries, like Nepal, are actively adapting to changing climatic conditions, demonstrating resourcefulness and resilience. The foundations of indigenous resilience remain rooted in communal systems of knowledge, values, and practice capable of both incremental and transformational adaptation to sustain cultural-ecological models of wellbeing. Energy systems, including heat, electric, and metabolic energy, are vital to any strategy of indigenous adaptation and development. The cultural dimensions of these systems should not be ignored (Adger et al. 2012).

Indigenous knowledge was recognised in the IPCC's Fourth Assessment Report as "an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change" (IPCC 2007a, b: p. 673). Indigenous knowledge is fundamental for diverse autonomous adaptation responses along a range of pathways. However, an adaptation-mitigation disconnect can appear when indigenous knowledge and adaptive capacities are ignored in adaptation planning. The Humla case study is an example of this adaptation-mitigation disconnect, with incremental adaptation along a diversification pathway leading to increased depletion of forests. Similarly, a number of Alaska Native communities are poised to transform their energy systems away from fossil fuel dependence and toward local renewables, but the costs of transformation are presently high enough that progress remains only incremental. To achieve significant mitigation of greenhouse gas impacts on a global scale, this adaptation must become truly transformative and also be expanded beyond the local and regional scales. Yet cost, feasibility, and unequal distribution of benefits versus burdens of adaptation programmes remain significant obstacles (Adger and Barnett 2009; Adger et al. 2009). Nevertheless, the scaling up of indigenous energy transformation initiatives and institutions across Alaska Native communities shows the potential for place-based adaptation through multi-local initiatives, conspecific learning, and the creation of new consortia, such as the multi-community Chaninik Wind Group in southwest Alaska.

Where indigenous communities are exposed to extreme or rapid climate change, incremental adaptation along existing or traditionally common pathways may not be sufficient. Transformational change may be necessary to escape maladaptive adaptation strategies that decrease future adaptive capacity. An understanding of how to support transformational change within indigenous and rural communities is thus critical in order to capitalize on synergies between development practices and adaptation and mitigation outcomes–mainstreaming adaptation and mitigation into development interventions. In Nepal this could support the diversification of livelihoods to improve food and fuel security and forest management. In Alaska policy support tools for transformation of the energy system could provide the economies of scale needed to sustain the alternative energy industries (Sikka and Thornton 2012).

Additional work, such as concerning the macro political-ecological conditions of transformation, is needed to further our understanding of how best to exploit synergies and trade-offs between adaptation, mitigation and development policy to reduce the deleterious effects of the current disconnect on indigenous peoples. An integrated approach supporting the full range of autonomous pathways, cultural dimensions and transformative factors relevant for adaptation has the highest potential to foster these synergies and optimise practical interventions by adaptation and development partners, be they states, NGOs, or other entities. Such an approach can harness the diverse strengths of existing community capacities and cultural assets, including indigenous and local knowledge, values, and ways of being, to support appropriate means of adaptation in response to the unprecedented challenges posed by climate change.

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