

ENVIRONMENT

Bridging indigenous and scientific knowledge

Local ecological knowledge must be placed at the center of environmental governance

By Jayalaxshmi Mistry¹ and Andrea Berardi²

Indigenous land use practices have a fundamental role to play in controlling deforestation and reducing carbon dioxide emissions. Satellite imagery suggests that indigenous lands contribute substantially to maintaining carbon stocks and enhancing biodiversity relative to adjoining territory (1). Many of these sustainable land use practices are born, developed, and successfully implemented by the community without major influence from external stakeholders (2). A prerequisite for such community-owned solutions is indigenous knowledge, which is local and context-specific, transmitted orally or through imitation and demonstration, adaptive to changing environments, collectivized through a shared social memory, and situated within numerous interlinked facets of people's lives (3). Such local ecological knowledge is increasingly important given the growing

global challenges of ecosystem degradation and climate change (4).

The insights that can be gained from local indigenous knowledge are illustrated by a recent study by Klein *et al.* (5). The authors show that local knowledge of climate and ecological change supports the hypothesis of delayed summers on the Tibetan Plateau. This question has been vigorously debated as a result of contrasting scientific data. Interviews with Tibetan pastoralists herding livestock on a daily basis and at higher elevations found noticeable changes in seasonality, higher snowlines, and long-term changes in animal numbers, which suggested a regional warming trend underlying delayed phenological trends. This was supported by pastoralists' perceived delays in the start of summer over multidecade time scales, thereby refuting the shorter-term trends revealed by normalized difference vegetation index (NDVI) measurements and reinforcing long-term remote sensing records.

Studies with the Inuit of the Arctic region (see the photo) also show that local ecological knowledge can reveal unexpected outcomes (6). For example, Idrobo and Berkes have shown that the Pangnirtung Inuit of

southern Baffin Island use experiential information, reflections, variations in knowledge, and sense-making to generate new understandings about the Greenland shark and its role in the Arctic marine environment (7). This includes knowledge about shark occurrence, habitat, and feeding behavior that is more detailed than the current scientific understanding of shark ecology. These studies show that when indigenous people seek to adapt to novel challenges such as climate change, they do not seek solutions aimed at adapting to climate change alone, but instead look for holistic solutions to increase their resilience to a wide range of shocks and stresses from various sources, some of which may have similar, or greater, negative consequences for their communities.

A growing body of published literature discusses the importance of indigenous knowledge and differing worldviews in ecosystem science and management (8, 9). Yet there is still a tendency among the scientific community to assimilate local ecological knowledge within Western worldviews of managing nature. Examples include community monitoring, reporting, and verification as part of the REDD+ policy (10) and the use of indigenous

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Respecting local knowledge. To be successful, efforts to protect biodiversity and respond to climate change must engage with local communities and start from the perspective of indigenous knowledge of local ecology. In this photo, Inuit hunters share the fresh meat of a newly shot seal, Baffin Island, Nunavut, Canada.

fire practices for carbon abatement. Both of these are attempting to institutionalize indigenous knowledge into existing environmental governance structures that are dominated by an incentive- and market-based approach to climate change mitigation (4). In the case of fire management, the accounting and metrics involved in monitoring new emissions-reducing programs is a dramatic shift from how local knowledge is usually embedded in practice, place, and dynamic decision-making (11). This approach risks further marginalizing indigenous people.

A major reason for the limited engagement with indigenous knowledge is the persistence of epistemological differences, and the associated politics of representation, within the social and governance context. Local ecological knowledge is seen as subjective, arbitrary, and based on qualitative observations of phenomena and change. Scientific knowledge, by contrast, is viewed as objective and rigorous, with precise measuring and empirical testing of events and trends confirming credibility and legitimacy. Attempts to evaluate local ecological knowledge thus often use scien-

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tific methods to prove its validity. However, all forms of knowledge, including scientific knowledge, are produced by socially situated actors and are value-laden (12).

Furthermore, the scientific approach, with its imperative for precise categorization and abstract generalization, rapidly loses its ability to provide useful guidance to the general public when faced with increasingly complex situations typified by uncertainty, nonlinear dynamics, and conflicting perspectives (13). Indigenous knowledge can circumvent some of these problems by generating a systemic understanding of a complex environment and integrating a large number of variables qualitatively over an extended period of time. Through collective and adaptive dialogue, indigenous knowledge can lead to simple rules that can be easily remembered and locally enforced through social means (14).

Conservation and development ideologies worldwide are heavily influenced by politically dominant Western agendas, and the structures in which indigenous knowledge is used and applied are determined by science. The danger is that in these places, indigenous knowledge will change in its use and applica-

tion, and, most critically, in its ability to deal with complexity. For example, the institutionalization of indigenous fire management has focused on protective early dry-season burning at the expense of regular and sometimes opportunistic burning throughout the dry season and in the wet season (11). This could lead to a loss in the complexity of fire knowledge, amplified by a general loss of traditional knowledge (especially among young people), which has serious implications for future indigenous cultures and their linked ecosystems.

Indigenous knowledge systems, and the processes for their evolution over time, can support rapid adaptation to complex and urgent crises (15). Rather than encouraging these knowledge systems to become more “scientific,” we urge a respectful acknowledgment of their distinctiveness and epistemology (16). We suggest that any effort to solve real-world problems should first engage with those local communities that are most affected, beginning from the perspective of indigenous knowledge and then seeking relevant scientific knowledge—not to validate indigenous knowledge, but to expand the range of options for action. This would make scientific knowledge more acceptable and relevant to the societies that it seeks to support, while critically promoting social justice and establishing self-determination as a key principle of engagement. ■

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IMMUNOTHERAPY

Outsourcing the immune response to cancer

Healthy donors provide T cells that target neoantigens in cancer patients

By Mahesh Yadav and Lélia Delamarre

One challenge in the field of cancer immunotherapy is to improve patient responses to current immune therapies that enhance the capacity of T cells to kill tumors by blocking inhibitory pathways called immune checkpoints. The recent identification of mutated proteins in tumors, called neoantigens, as the main targets of effective antitumor immunity offers the opportunity to design therapies that stimulate highly focused antitumor T cell responses (1). On page 1337 of this issue, Strønen *et al.* (2) report that a much greater frequency of tumor mutations are immunogenic than initially estimated, and that healthy donors can provide T cells that are reactive to these neoantigens. The findings point to a new individualized approach for expanding immunotherapies.

Cancers can accumulate hundreds of mutations. How many of these mutations are immunogenic is unclear. For a neoantigen to be immunogenic, the mutant protein has to be processed, and the resulting mutant peptide needs to be presented by major histocompatibility complex (MHC) molecules. Also, the MHC-mutant peptide complex must be recognized by the host's T cells. Based on preclinical evidence and immune monitoring of cancer patients, it is typically thought that only a very small fraction of expressed tumor mutations (<1%) are immunogenic in cancer patients (3, 4). However, the tumor microenvironment presents major challenges to antitumor T cell responses. In addition to inhibiting existing T cell responses, the microenvironment can prevent adequate T cell priming or induce immune system tolerance to the tumor (5). How,

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