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Edges, Seams, and Ecotones: Error in Interstate Landscapes

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This article explores the nature and function of error in *interstate landscapes*: the odd and blended spaces where different ecologies meet and mix. It speculates on how a more integrative and generative notion of error may change our thinking around categories and classifications in sociotechnical systems more generally, inviting alternative and more embodied ways of knowing.

Keywords: error, ecology, residual category, interstate landscapes

This article addresses a particular kind of error: that which occurs in *interstate landscapes* where different worlds, orders, and environments meet, mix, and push against the categories and logics of binary separation. What does error look like in such edgy and unsettled landscapes? How might we uncover or imagine its presence? And above all, *what work does error do* (1) as an *analytic* to disclose worlds; and (2) as a practical illustration of how spaces are worked on, worked through, and worked out in the large and small, spectacular and mundane, heroic and utterly boring details of everyday interaction?

This article approaches error not as something that *divides* normal from abnormal, correct from incorrect, but as a rough and continuous *edge* or "seam of relationality" (Fujikane, 2021, p. 19) that joins while holding apart manifest differences in kinds. We draw inspiration from Candace Fujikane's (2021) work on Kanaka Maoli ecological knowledge such as the concept of "moʻoʻ¯aina," which locates smaller land divisions as part of a larger land base (p. 19). In this world, ecological space is continuous rather than divided; clouds are not simply amorphous features in the sky but also materials that "water the mountaintops with rains that travel down in streams," which then feed taro pond fields, which in turn return nutrients to the streams (Fujikane, 2021, p. 20). Errors in these environments may be understood to occur when different worlds, orders, and environments create what Fujikane (2021) refers to as a "lateral relationality of ecosystems" (p. 19): a loopy and nonlinear world defined by abundance in interaction, excess in proliferation, and the constitutive and inseparable relation of parts and wholes.

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Errors may also be understood from the standpoint of remainders, residues, and residuals—the inevitable leftovers and left behinds of purportedly universal systems of classification and knowledge. Errors that refuse to be absorbed can become what Star and Bowker (2007) have called "residual categories"—the things, people, and landscapes with no column in the spreadsheet, or too many mutually exclusive columns at once (such as the legally impossible people that apartheid regimes, then and now, have regularly produced). Even once "discovered" these errors may remain stubbornly present, at once "in" and "out" of the system, made partly invisible by the category work around them and *yet still there*, generating a kind of "excess" that challenges the categories and practices around them and embedding a "world of many worlds" (Blaser & de la Cadena, 2018, p. 4) in the very heart of our sociotechnical systems. To attune to the presence and persistence of errors (without immediately seeking to fix or resolve them) is to take seriously the alternate worlds that errors index and invite. Living artfully with error is one more way of "stay[ing] with the trouble" (Haraway, 2016, p. 2).

We will illustrate this point through examples from our fieldwork in ecology and the earth sciences—fields still fertile and underexplored within media and technology studies. Such spaces, especially where they meet the "categorical imperative" of modern science and technology, offer opportunity to rethink the meaning of residual categories, and teach us something about error as a sociomaterial phenomenon. We explore the role that errors hold and play in these worlds and the challenges (and opportunities!) they pose to work, understanding, and everyday practice. Some of our lessons concern relationships between error, sorting, and classification central to contemporary sociotechnical systems. Others go beyond systems and artifacts to consider how errors may shape and inflect the basic (un)knowability of worlds themselves.

Edges and Ecotones as Residual Category

As any ecologist will attest, edges and ecotones—the rich meeting place of biomes and zones where worlds otherwise distinct gather and transact—are weird. They contain species that would not normally interact, and across most of their range, do not. Ecotones may be fragile and susceptible to change (including changes attached to global or human disturbance). Or they may be durable and resilient, with capacities to persist and adapt that stem precisely from their odd bioecological combinations. They are the platypi of the biome world (weird mammal or failed duck?) and as such challenge easy efforts to bound or classify. And as any permaculture farmer would confirm, they are also vibrant, generative, and profuse, almost always more so than the ecologies they border and connect. Pound for pound and foot for foot, edges and ecotones are among the most generative landscapes on the planet.

But as "residual categories," ecotones pose exactly the kinds of challenges of uncertainty and coordination in which error proliferates and which ecologists are always working to manage, define, and contain. Consider for example the crucial distinction between rock and permafrost (essential to the measurement of Arctic land change and global climate as a whole) and the crucial modes of touch and feel that are required to distinguish these states. One discussion of ecological fieldwork stresses the subtle material differences key to the management of error in this space:

> So one of the things you can read about in the protocol, it says, "Make sure that you're hitting ice, that you're hitting frozen soil and not a rock because the rock will stop you just like the ice will stop you." And you could read that all day and never know the difference between a rock and the ice. You wouldn't know that in the field unless you actually had a feel for it and someone was there telling you: Dink! "Hear that sound?" "Yeah, I haven't heard that before." "Yeah, that's a rock. Now move it a little bit over and do it in the permafrost, that is the ice. Do you see the difference?" "Yes" "Do you feel the difference?" "Yes." Done. (Jackson & Barbrow, 2015, p. 4)

Other kinds of interstate landscapes and errors may be found in the ground beneath our feet. Soil scientists have long sought to untangle the mysteries of soil, the permeable zone in which most gas and nutrient exchange crucial to life takes place. Part gas, part solid matter, and shot through with life forms of all kinds, soil is also one of the slowest moving things on earth, accumulating under temperate conditions at approximately 1000 years per inch—drive a shovel all the way into the ground, and its tip reaches the ice age. And soil processes, while poorly understood, are hugely consequential: Global soil depletion and degradation threaten human well-being no less existentially than better-understood problems of climate change and contribute directly thereto, from carbon fixing in plants to termite methane releases—yes, termite farts—soil processes account for approximately one quarter of the greenhouse gas emissions of the global coal industry (Eberle, 2022).

In data terms, soil is noisy. It is hard and expensive to study, unwieldy to transport, and studied through messy processes of sampling and extraction that disrupt and destroy many of the processes that scientists are most interested in understanding. But as the growing field of soil acoustics attests, soil is also *literally* noisy, offering possibilities of less invasive "listening" to soil to predict its health and productivity. The burrowing of worms and grubs, the sounds of roots growing, the drumming and filtration of water after a rain—all of these constitute a complex subterranean soundscape that soil scientists have hypothesized alongside the better-known pathways of chemical exchange as a core medium of floral and faunal signaling and exchange (Maeder, Guo, Neff, Schneider Mathis, & Gossner, 2022). But at this early stage in the field, the sounds remain muddled and recordings prone to mistakes. What is grub and what is root? How to account for the effects of travel and attenuation in variably dense and discontinuous media? Which noises are artifacts, and which are sounds? In this complex interstate landscape, when is silence a measure of morbidity (soils deadened by monocropping, pesticides, and depletion), and when is it a failure of measure and imagination?

Peatland and Permission for Error

Similar challenges confront the study of peat. Home to one of the world's largest tropical peatlands, Indonesia has become an important site for conserving such landscapes. Understood by scientists as holding twenty times more carbon than tropical rainforests in a same-sized area, tropical peatlands are often promoted as a key landscape for reversing the fate of a warming planet (United Nations, 2022). They are also interstate landscapes *par excellence*, a strange and evolving blend of land and water, dome and edge, that challenge both land classification and the disciplinary organization of the sciences. While scientists and policymakers worldwide have promoted the ecological importance of

peatlands for reducing future carbon emissions, peatlands have been cleared extensively to advance Indonesia's industrial plantation economy.

To protect peatlands, the Indonesian government has implemented a regulation and criteria for what kind of peatlands are designated for conservation. This includes areas where a layer of peat is at least 3 meters (10 feet) deep. This regulation also requires at least 30% of peatland surrounding its dome to be conserved. While some scientists do not agree with these numbers, they understand that these legally binding definitions stem from a historical context in which there was no prior data or map of tropical peatlands in Indonesia. Part of this was driven by the dominance of colonial science in Indonesia, with European scientists denying the existence of peatlands in the tropics until the early 1900s (Joosten, 2016). Concurrently, Dutch colonial officials regarded tropical peatlands as wastelands, often seeking to drain and "reclaim" them for cash crop production. This resulted in peatlands being viewed as unworthy of conservation and set the precedent for the rise of industrial plantations in postcolonial Indonesia.

As such, scientists have worked within and sometimes against the bounds of such official categories to develop strategies to map and preserve peatland, despite having no official record of its location. As a government scientist from Indonesia during one field survey in 2019 told us, "It doesn't matter if the peat is 3 meters deep or not. As long as it is 1 meter, I will categorize it as peat as all peat is susceptible to fire." Government scientists rely on their touch, sight, and surrounding ecology to trace the integrative edges of peatlands. One such strategy includes jumping on the boggy ground. If their feet sink, or if the land feels springy after a few jumps, scientists classify the ground as peat worthy of conservation. Soft, squishy, and watery, peatland moves with every step one takes.

Peatlands are also located based on their susceptibility to fire. Drained by the canals of industrial plantations, they have become an effective medium for fire. Scientists learn to gently sweep debris on the ground with their feet. If smoke rises, there is a strong likelihood that fires are smoldering and traveling through peat, indicating some depth (some can go above 7 meters!). The last step includes scanning the surroundings for plants likely to grow after a peatland fire. One of the most sighted plants is gelam, a wetland tree naturally distributed in lowland peat swamp forests throughout Indonesia. Nearby farmers collect and harvest gelam wood, thriving in interstate landscapes once deemed as impossible for plants to grow on (Ulya, Waluyo, Nurlia, Rahmat, & Martin, 2021).

In all, scientists are willing to work with the limits of legal binding definitions to regard *all* peatlands as vulnerable to fires and therefore worthy of conservation. This is no doubt a fair practice, given that almost 87% of tropical peatlands in Indonesia have suffered from drainage, deforestation, and extensive agricultural expansion (Yuniarto, 2023). In ensuring that all peatlands, including shallower peat, are categorized as susceptible to fire, scientists in Indonesia ensure that "lost peatlands" are accounted for in consideration of carbon storage and their contributions to the wider peat ecology. In other words, the struggle to legally categorize and protect tropical peatlands demand scientists to develop new and strategic thresholds for "errors" in sensing and measurement.

Conclusion

How might these strange travels through the interstate landscapes of semifrozen earth, noisy soils, and watery peatlands change how we think about error in media and technology studies today? First, they may help us to move beyond a binary imagination of error, where data points are right or wrong, land or water, rock or ice. (Sometimes we cannot know; sometimes they are both). An appreciation for such dynamics may help to push against the presumption of fixed and stable ontologies and the easy work of classification in mixed and blended sociotechnical landscapes, showing them instead to be fluid, shifting, and volatile ecologies. This includes the myriad sites of technical interface between systems, the innumerable handshakes, gateways, and transit points that allow data and knowledge to move and flow through infrastructure (and the world at large). It also includes the categorization of humans themselves who in systems from algorithmic prediction to gender or racial categorization to the myriad infrastructures of border crossing and mobility are *also* rock and ice, cloud and smoke, land and water. Learning to live with error in interstate landscapes of all kinds may thus be essential to both practice and justice in a radically mixed and variegated world. Finally, interstate landscapes show how errors may shape and inflect the basic (un)knowability of the world itself, preserving spaces of silence, uncertainty, and impossibility in the noisy, glitchy, and never-quite-seamless sociotechnical systems around us.

Second, recognizing and reclassifying the ineluctable errors in interstate landscapes may help to better preserve alternative knowledge practices in spaces of mixture and complexity. Mixtures of ice and rock, for instance, rely on forms of touch and feel that follow embodied, present, less-distanced, or nonbinary categories of experience. This focus on embodied experience applies (or should) to human worlds of media and messages, infrastructures and classifications, which Katherine Hayles (1999) has rightfully pointed out can become erased when "intelligences become a property of the formal manipulation of symbols rather than enaction in the human lifeworld" (p. xi). This also suggests new modes of disciplinary learning and alignment, including from fields (like peatland restoration or soil acoustics) that have been traditionally far from the concerns of media and information scholars but that could provide new insights and imaginations. What might a boots-in-mud, dirt-under-fingernails media and information studies look like? Could reimagining error in this way support more open, embodied, and multisensory understandings of our contemporary sociotechnical worlds?

We live in a world of gradients, edges, and ecotones of things and people who are always more than the narrowness of their categorizations. It is also a world of motion, comings and goings, and every state of transformation, a world far more rhythmic than algorithmic. The contemporary moment must begin with this fact: As borders and lines are crossed, every minute and every day the presence and prevalence of error only increases. Can we recall a state of difference across borders that is not an occasion for war? Can we arrive at a concept and practice of error that orients not only toward correction, deletion, and eradication but also generativity, profusion, and the ineradicable presence of the different and the new? Beyond bias, beyond fairness, perhaps even beyond justice, this would be a media and technology studies worthy of the moment.

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