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RESEARCH ARTICLE

Equity in ecosystem restoration

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The importance of equity has been emphasized in climate change, biodiversity loss, land degradation, and ecosystem restoration. However, equity implications are rarely considered explicitly in restoration projects. Although the role of equity has been studied in the context of biodiversity conservation and environmental governance, environmental variables are often ignored in equity studies, and spatial analyses of equity are lacking. To address these gaps, we use a mixed methods approach, integrating spatially explicit ecological and social data to evaluate, through an equity lens, a restoration project in a semi-arid rangeland socioecological system in Kenya. We use questionnaires and semi-structured key informant interviews to explore four dimensions of equity: distributional, procedural, recognitional, and contextual. Our results show that restoration employment and distance to the restoration site strongly influence perceived distributional and procedural equity. Employment and distance to restoration site can interact in counterintuitive ways in their influence on aspects of perceived equity, in this case, the fairness of site selection. Our findings exemplify that equity dimensions are intimately linked, and trade-offs can occur between equity dimensions, across socio-temporal scales, and in choosing the ethical framework to apply. Our work demonstrates how restoration is influenced by different dimensions of equity and we opine that incorporating equity in project planning and implementation processes can improve restoration outcomes. We emphasize the importance of respecting plurality in the values systems and ethical frameworks that underlie what is considered equitable, while negotiating trade-offs between diverse ethical positions in the design and implementation of ecosystem restoration projects.

Key words: community-based restoration, equity, invasive alien species, *Opuntia stricta*, social and environmental justice

Implications for Practice

- Ecological outcomes of restoration projects may benefit from improving equity.
- Different dimensions of equity are intimately linked, and trade-offs can exist between equity dimensions, in the choice of ethical framework to apply, and across socio-temporal scales (e.g. focal/other communities or current/future generations), as well as between equity and ecological objectives of restoration. Consequently, maximizing equity in one particular dimension may come at the expense of another equity dimension or the ecological outcomes of restoration.
- Restoration practitioners should be mindful that factors influencing perceived equity can interact in counterintuitive way and must respect a plurality of value systems and ethical frameworks when negotiating trade-offs between diverse ethical positions.

Introduction

The importance of equity has been highlighted across multiple global-scale issues such as climate change (IPCC 2014), biodiversity loss (CBD 2013), land degradation (IPBES 2018), and ecosystem restoration. The United Nations Decade on Ecosystem Restoration (2021–2030) stresses the importance of recognition and procedural aspects of equity: the participation of relevant stakeholders, including women, young people, persons with disabilities, indigenous peoples and local communities (UN 2019). Ecosystem restoration is inherently value laden and prone to disagreement and compromise (Egan et al. 2011; Jordan 2003). Restoration often involves (in)equity, from the structural societal disparities that can underly ecological degradation that necessitates restoration (IPBES 2018;

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Schell et al. 2020) to restoration prioritization (Crossland et al. 2018; Dallimer & Stringer 2018) and the distribution of the costs and benefits associated with restoration work (Jewitt et al. 2014). Equity can be defined as the "fair or just treatment of individuals or groups" (Law et al. 2017), and is comparative, principally concerned with relationships between people (McDermott et al. 2013). Equity has many facets, including social (human-centered equity), environmental (equity related to environmental issues), intergenerational (responsibilities to future generations), and the consideration of nonhuman life (Schlosberg 2013) or entities (e.g. spirits; Martin et al. 2016). The importance of equity has been discussed in the context of biodiversity conservation and ecosystem governance, often in the form of environmental justice (Martin et al. 2013; Sikor et al. 2014). However, in conservation research, qualitative methods are poorly implemented and reported (Young et al. 2018), while environmental variables are seldom included in equity studies (Friedman et al. 2018) resulting in many knowledge gaps. Equity is rarely addressed in restoration projects (but see Jewitt et al. 2014), as are social science methods more generally (Aronson et al. 2010; Wortley et al. 2013). We aim to contribute towards filling these gaps by employing a mixed methods approach to considering a restoration project through an equity lens.

Equity can be decomposed into four dimensions: distributional, procedural, recognitional, and contextual (Pascual et al. 2014). Distributional equity refers to the equitable sharing of costs, benefits, rights, responsibilities, and risks. Most equity studies focus on distributional equity, because it is the most recognizable and easiest to quantify (Friedman et al. 2018). Procedural equity refers to equitable involvement of stakeholders in making rules and decisions. Recognitional equity refers to the respect for knowledge systems, values, social norms, and rights of stakeholders. Contextual equity refers to the broad social, economic, political, and cultural contexts, both past and present, that influence the ability of an actor to participate in decision-making, ensure fair distribution, and gain recognition: for example, power dynamics, ethnicity, gender, age, and education (Pascual et al. 2014).

Motivations for considering equity in restoration projects can be instrumental (outcomes based, e.g. utilitarian), intrinsic (fundamental, e.g. virtues), or both—as is also the case for restoration itself. Implementing restoration equitably in order to improve project success is an example of instrumental motivation. Pursuing equity because it is inherently right or valuable, regardless of benefits to restoration outcomes, characterizes intrinsic motivation. The motivation for equity is predicated on ethical frameworks. Different ethical frameworks can lead to different perspectives on what is considered equitable, which can conflict (Law et al. 2017).

We assess both ecological and social aspects of a restoration project by addressing three main questions: (1) "what effect did the restoration work have on invasive species prevalence and animal (domestic and wild) habitat use?"; (2) "what role does equity play in ecosystem restoration?"; and (3) "how do spatial attributes influence equity?" By investigating how restoration work is influenced by different dimensions of equity, we explore how incorporating equity in planning and implementation processes could influence restoration success.

Methods

Conceptual Framework and Research Design

Building on work by others, we develop a conceptual framework for how equity relates to restoration (Fig. 1), in order to frame the concepts that underpin our research design. We adapt

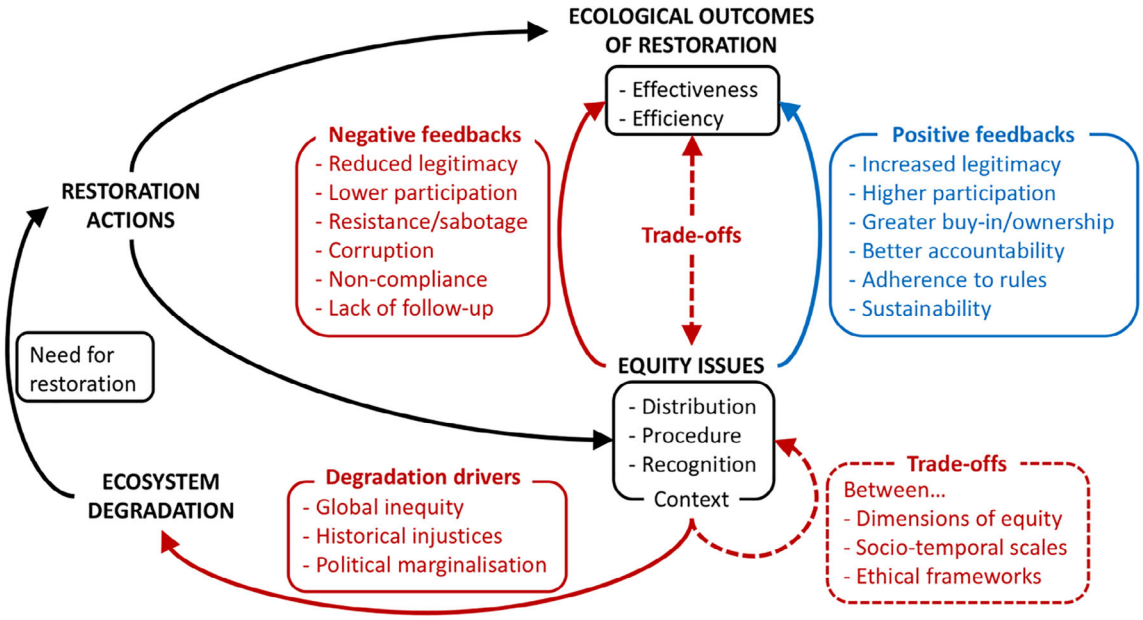


Figure 1. Conceptual framework for the role of equity in restoration, highlighting processes that positively (blue) or negatively (red) impact restoration or equity objectives. Adapted from Pascual et al. (2014).

the conceptual framework relating equity to payments for ecosystem services schemes developed by Pascual et al. (2014). We incorporate the role of equity in ecosystem degradation and the need for restoration reviewed by IPBES (2018), as well as the trade-offs identified by Law et al. (2017). In short, our conceptual framework illustrates that the four dimensions of equity influence drivers of ecosystem degradation, and thus the need for restoration, while impacting the efficiency and effectiveness of restoration outcomes via feedbacks, both positive and negative. Trade-offs can exist between equity dimensions, in the choice of ethical frameworks to be applied, and across socio-temporal scales (e.g. focal/other communities or current/future generations), as well as between equity and ecological objectives of restoration. We developed this hypothetical framework a priori to organize our thinking and the research design. We did not intend to systematically validate it during the research.

The stages of our research process, listed chronologically, were as follows: (1) identify the community's most highly prioritized ecological issue (*Opuntia stricta* invasion) and codevelop possible solutions (ecological restoration); (2) develop a research question ("what is the role of equity in restoration?"); (3) codevelop methodology for restoration work; (4) implement the restoration work; (5) organize a scoping workshop to frame the equity issues; (6) conduct questionnaires designed using important equity-related questions identified in the scoping workshop; (7) identify key informants using stakeholder mapping (using a power/interest matrix) and conduct key informant interviews using semi-structured approach based on the results of the questionnaires. We followed the iterative nature of grounded theory, in which the results of data analysis informed further data collection.

Study Site

Livestock grazing lands cover 80% of Kenya's area and account for over 12% of gross domestic product (Allan et al. 2017). We conducted this study in a 6,816 ha predominantly Maasai communally managed rangeland, called Makurian group ranch (hereafter, Makurian), in Laikipia, Kenya. The ethnicity of the community is almost entirely Mukogodo Maasai. Kenya is a biodiversity hotspot in which livestock-keeping plays an important role for livelihoods and culture. Rainfall is weakly trimodal with a pronounced dry season December–March. From 2001 to 2019, annual rainfall averaged 460 mm/y¯ear (range: 231–929 mm/year, annual coefficient of variation: 35%). Soils are haplic and chromic luvisols and vegetation is predominantly *Acacia etbaica* (syn. *Vachellia etbaica*) and *A. drepanolobium* (syn. *V. drepanolobium*) savanna. *O. stricta* is a problematic cactus species that has become invasive and/or naturalized in many countries (CABI 2020). *O. stricta* was introduced to Laikipia by a colonial administrator in the 1950s and has spread exponentially, assisted by rangeland degradation (reduced vegetation cover and increased soil erosion) associated with livestock grazing and settlements (Strum et al. 2015). The dispersal of *O. stricta* is aided by wildlife that consume its fruit, particularly baboons (*Papio anubis*) and elephants (*Loxodonta africana*). The attraction of elephants to pastoral settlements, where the cactus is often more prevalent, may increase human wildlife conflict (Strum et al. 2015). In the study area, *O. stricta* was perceived by local residents as a more severe issue than insufficient grazing, largely because it restricts access to pasture and its glochids (small barbs) lead to secondary infections and sometimes death in livestock (Shackleton et al. 2017).

Restoration Work

This project focuses on reinstating ecological functionality (rather than aiming for recovery relative to a local native ecosystem) and could be thought of as "rehabilitation" (between "repairing ecosystem function" and "initiating native recovery" on the restorative continuum; Gann et al. 2019). However, the project aimed to assist the recovery of an ecosystem that has been degraded/damaged/destroyed, so we use the term "restoration".

Community leaders—members of the group ranch committee and representatives of the 11 "clusters" (or sub-communities) within Makurian, called *nyumba kumi*—identified a restoration site to fit three co-established criteria: (1) *O. stricta* cover >50%; (2) conserved for dry season grazing, because higher herbaceous cover in conserved areas may slow *O. stricta* reestablishment (Strum et al. 2015); and (3) proximity to a building to securely store tools. The group of community leaders, together with the lead researchers (H.B.M.W. and E.H.K.), codeveloped a list of alternative approaches to *O. stricta* management including: (1) mechanical removal with heavy machinery; (2) manually assisted dispersal of flightless biocontrol agent, cochineal (*Dactylopius opuntiae*); (3) burning spines and glochids to allow safe ingestion by livestock, and (4) manual removal. From this list, manual removal was chosen based on expected cost-effectiveness. Cut and/or uprooted cacti were collected into tall piles, which is cheaper than alternatives such as burning or burying. Another rationale behind the piles was to encourage passive cochineal establishment (each pile had at least one infected cactus), without costly propagation and spreading of the biocontrol agent. We purchased tools (wheelbarrows, hoes, spades, gloves, machetes, garden forks, rakes) and employed community members to manually clear the cactus. Community leaders chose employment over volunteering, despite acknowledging the risks of "crowding out" values, in which moral obligations to restore ecosystems are replaced by finance or regulation (Moon & Cocklin 2011). A total of 91 individuals were employed (59 males, 32 females; median age: 34 years, age range: 21–58 years), each for between 5 and 17 days, in January/February 2020 (the dry season), clearing a 21-ha area located in one cluster. Prior to this clearing event, between April and July 2019, the tools were used for 1-day voluntary *O. stricta* clearing events in all 11 clusters at sites chosen at the cluster level. The purpose of this was to (1) share the benefits of *O. stricta* clearing across all clusters, and (2) develop an effective piling technique (e.g. pile size) for the 21-ha restoration work. The importance of voluntary work in restoration has been recognized, with respect to project implementation and sustainability as well as the well-being of volunteers (Egan et al. 2011). Before and after the 21-ha area was cleared, the tools were

equally distributed among the clusters, where they rotated among households to clear *O. stricta* around homesteads.

Data Collection and Analyses

We assessed local perceptions of various aspects of equity. Although perceptions are often criticized for being subjective, inaccurate, and unreliable, they provide an important form of evidence in conservation and environmental management (e.g. Bennett 2016). The distributional and procedural pillars of equity were evaluated primarily using the questionnaires and key informant interviews. We assessed recognitional equity using participant observation practiced throughout the project, while assessing contextual equity using a literature search and key informant interviews.

The scoping workshop attendees were selected through stratified random sampling to include men and women of varying ages, both employed and not employed by the restoration project, from all 11 clusters. All selected individuals attended the workshop. The scoping workshop was structured as a large focus group discussion to both frame and identify equity issues. The large number of participants (n = 44) had the advantage of more balanced representation (four randomly selected men/-women who were employed/not employed by the project from each cluster), but increased the potential for biases due to group think, dominance effects, production blocking, information cascades, and/or social loafing (Mukherjee et al. 2018).

Both questionnaires and unstructured key informant interviews are suitable methods for monitoring and evaluating projects involving communities (Mukherjee et al. 2018). The questionnaires collated low-resolution perspectives of a large representative sample of the community (n = 232), while the key informant interviews allowed a more in-depth, higher-resolution exploration of equity-related issues with a small number of respondents (n = 4, one male/female community leader and local government official). The key informant interviews were also used to provide context and clarity in interpreting the questionnaire responses. E.H.K., who is a member of the Makurian group ranch, translated between English and Maa and conducted the questionnaires alone to reduce bias in the responses (e.g. respondents would feel more comfortable expressing criticisms). The sample size for the questionnaires was such that at least one individual from each household willing to be interviewed took part. The questionnaires included binary (yes/no) and Likert scale (1–5) questions, as well as a priority ranking exercise to order the issues covered in the questionnaire by relative importance (1–12, 12 being the most important). We conducted the questionnaires orally, in person, and one-to-one (Supplement S1). We conducted key informant interviews as a mixed-sex group (one man, H.B.M.W., one woman, C.L.C., and one male interpreter, E.H.K.) in an attempt to elicit more balanced and complete responses. This was a recommendation by several community members, particularly regarding gender equity issues.

In the process of analyzing key informant interviews, we borrow from constructivist grounded theory. This variant of classic, positivist, grounded theory (Glasser & Strauss 1967; Chametzky 2016) aims for interpretive understandings and situated knowledges, reflecting on positionality and particularities, and views data as value laden and coconstructed by researchers and research participants (Charmaz & Bryant 2010). We used participant observation throughout the project to add data that were not captured in the interviews (Reed & Dougill 2010).

We recorded variables of interest that may influence perceptions of equity: distance from homestead to restoration site (using the *distance to nearest hub* function in QGIS version 3.4.8), individual/household wealth (sum of the number of cattle, sheep, goats, donkeys, and camels multiplied by their respective exchange values—see Table S1 for details), employment status (employed or not employed by the restoration project), gender, age, marital status.

We assessed *O. stricta* densities and domestic and wild animal habitat use as ecological outcomes of restoration. To do this, we counted *O. stricta* plants and dung piles along twenty 100-m belt transects (Kimuyu et al. 2017), 10 of which were within the restoration site and the other 10 in an adjacent control site with comparable slope, soil type, vegetation type, and land management (conserved for dry season grazing). These transects were sampled 8 months after *O. stricta* was cleared to ensure that dung deposited prior to the restoration work had disintegrated and were not counted.

Maps of the probability of *O. stricta* presence (occurrence probability) were produced using the Land Degradation Surveillance Framework methodology (Winowiecki et al. 2018). At 654 random sampling locations we recorded *O. stricta* presence/absence in a 1,000 m^2 area using the Invasive Species Mapper application (https://www.rcmrd.org/). We employed a machine learning algorithm, extreme gradient boosting, to predict *O. stricta* occurrence probability using all eight bands of Landsat 8 tier 1 surface reflectance imagery (dropping plots for which the quality assessment band indicated cloud cover) taken as close in time as possible to the field surveys. We randomly assigned 70% of the field data for training and 30% for validation. The predictions performed well, evidenced by *O. stricta* presence/absence being correctly predicted in 83% of validation data.

For the literature search to investigate the role of contextual equity, we used "Maasai," "colonial," and "Laikipia" as search terms in Google Scholar. Although alternative methodologies such as gathering expert knowledge can provide more detailed and nuanced understandings of contextual equity, we chose a literature search to provide a broader range of perspectives and because both past and present contexts of the region have been extensively studied (e.g. Hughes 2006; Letai & Lind 2013). To search for literature to help develop a conceptual framework and a theoretical equity-restoration relationship, we used the search terms "equity" or "justice" with either "ecosystem/ecological restoration" or "conservation" in Google Scholar.

We used analysis of variance to test correlations between (1) perceptions of equity (de Winter & Dodou 2010) and variables of interest (distance, employment status, wealth, gender, age), and (2) densities of animal dung piles and *O. stricta* plants. *Opuntia stricta* densities and wealth were log-transformed to

normalize. All statistical analyses were performed in R version 3.6.2 (R Core Team 2019).

Results

Restoration Outcomes

Remote sensing derived predictive maps show that Makurian has the highest mean *Opuntia stricta* occurrence probability of all communally managed properties in Laikipia (Makurian = 0.57, restoration site = 0.63; Fig. S1). The belt transects revealed that *O. stricta* densities were 41% lower in the restoration site compared to the control site ($F = 3.4$, $p = 0.08$) 8 months after restoration work, during which nearly all cacti were uprooted. The cacti in the cleared area were reestablishing from fragments and were therefore smaller than mature plants in the control site (personal observation). Dung surveys revealed that livestock were preferentially herded in rehabilitated areas. The density of dung piles of sheep, goats, and cattle decreased 60% ($F = 8.0$, $p = 0.01$), 69% ($F = 10.9$, $p = 0.004$), and 36% ($F = 4.3$, $p = 0.05$) for every 1,000 plants/ha increase in *O. stricta* density (Fig. 2). Dung surveys also revealed a preference by elephants—the primary human-wildlife conflict species—for areas with higher *O. stricta* density (180% greater dung pile density for every 1,000 plants/ha increase in *O. stricta* density, $F = 1.7$, $p = 0.21$), but this result was not statistically significant. Although responsibility towards the needs of wild species was not explicitly considered by the community, zebras (*Equus quagga*) and hares (*Lepus saxatilis*) appeared to prefer rehabilitated areas, respectively showing 90% ($F = 4.8$, $p = 0.04$) and 82% ($F = 6.0$, $p = 0.03$) lower dung pile density for every 1,000 plants/ha increase in *O. stricta* density.

The perceived benefits of the restoration work were 25% higher among individuals employed by the project compared to those not employed ($F = 99.6$, $p < 0.001$). Perceived benefits declined by approximately 9% for every 10 km from the restoration site overall ($F = 6.6$, $p = 0.01$) and for those not employed by the project ($F = 5.2$, $p = 0.02$), but declined nonlinearly with distance to restoration site among those employed (second-degree polynomial: $F = 4.4$, $p = 0.02$). Most (89%) benefited from *O. stricta* clearing around their homestead, while many reported livestock health improvements (96%, in every case due to reduced consumption of *O. stricta*), increased shade (100%, due to removal of cacti beneath trees), ease of passage through the area (100%), and reduced conflicts with wildlife (97%).

Equity in Restoration

Our results show a variety of ways in which equity plays a role in restoration work. We consider the results of each of the four pillars of equity in turn starting with contextual equity to situate the results of the distributional, procedural, and recognitional pillars. We then present a theoretical relationship between equity and the degree to which ecological outcomes of restoration are met, developed from a combination of our empirical data (questionnaires and key informant interviews) and a literature search.

Contextual Equity

Contextual equity encompasses both present and past contexts. Historical injustices play a key role in contemporary ecosystem degradation—and therefore the need for restoration—in Maasai community managed rangelands in Laikipia. This began in the early 1900s when Maasai territory was greatly reduced by the British colonial government forcibly moving certain Maasai sections into two reserves, the northern of which included part of what is now Laikipia (Hughes 2006). Although these reserves were committed to the Maasai in perpetuity under the 1904 Maasai Agreement, the British reneged on the agreement in 1911, moving the Maasai from the northern reserve into an expanded

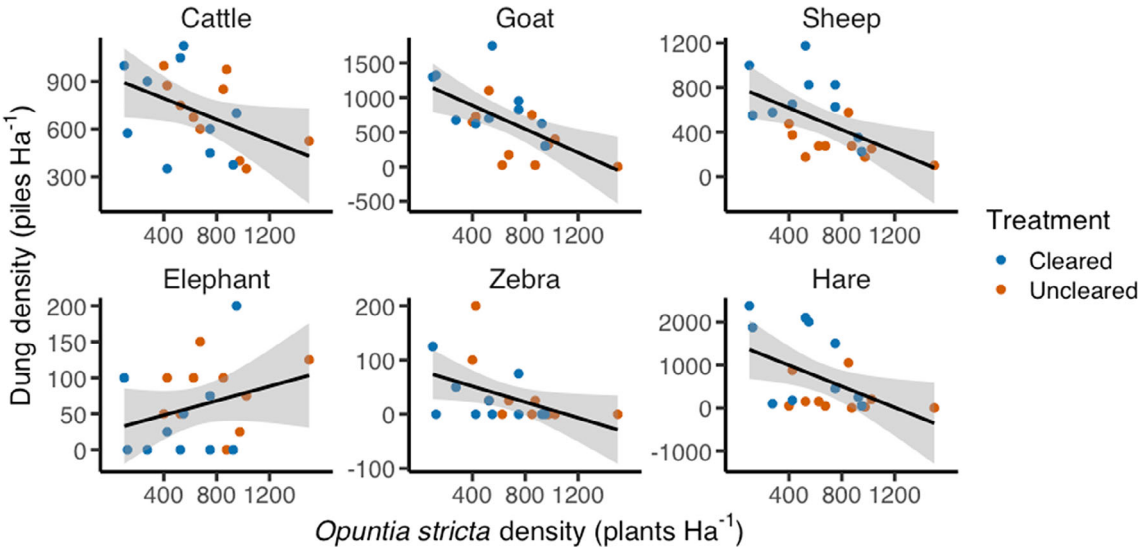


Figure 2. Correlations between *Opuntia stricta* density and dung pile densities of domestic (top row) and wild (bottom row) species. Dung densities are a proxy for habitat use. Trend lines show linear models with ±SE.

southern reserve to make way for European settlement. This latter move was sanctioned by a second agreement, but Maasai contend that their leaders signed under duress (Hughes 2006). The Maasai who remained in Laikipia were predominantly from the Mukogodo sections, who affiliated with forest-dwelling Cushitic-speaking foragers (hunters, gatherers, and beekeepers), who were treated more sympathetically by colonial administrators (Cronk 2004). The Mukogodo Maasai also lost access to grazing land and key resource areas through the demarcation of a forest reserve in the 1930s and land privatization and subdivision for both agriculturalist Kikuyu and elite Maasai, during and after independence in 1963 (Letai & Lind 2013). This history of land expropriations and associated suppression of mobility, together with population growth, increased pressure on the remaining rangelands accessible to the Mukogodo Maasai, contributing greatly to land degradation.

By contrast, the key informant interviews revealed a perception, held particularly by the two local government officials, that weak governance was one of the primary drivers of land degradation, not poverty or marginalization. They pointed to the considerable income from selling sand harvested from seasonal rivers at the group ranch level, a small proportion of which could be used to finance restoration efforts. One key informant stated that "if sand harvesting was well managed, Makurian would be one of the richest group ranches in the area … and … should not have any problems [with land degradation]." Another key informant commented "these group ranches are not so poor to the extent that they can't sustain some of these [restoration] projects on their own."

Distributional Equity

The mean perceived distributional equity (fairness of the distribution of costs and benefits of restoration) was 4.1 of 5. Perceived distributional equity was 5% greater for people employed than those not employed by the restoration project ($F = 33.2$, $p < 0.001$). Among those employed, perceived distributional equity increased 20% with every 10 km from the restoration site ($F = 4.0$, $p = 0.05$). One of the suggestions from key informant interviews as to how to improve equity was to organize clearing events within each cluster. This would mitigate the inequity stemming from people living further away benefiting less, particularly for those employed. Another suggestion was to involve disabled people, either directly or by prioritizing their relatives for employment.

The community ensured that poorer families received a greater share of the benefits of employment. Over 96% of respondents reported that poorer families (poverty was subjectively defined by respondents) were prioritized for employment, which was corroborated by result that employed individuals were 18% poorer than those not employed by the project ($F = 21.6$, $p < 0.001$).

Distributional equity appeared to be influenced by age but not gender. Less than 23% of respondents (women: 28%; men: 20%) felt that gender affected how costs and benefits were shared. By contrast, 87% of respondents felt that age affected how costs and benefits were shared, largely because old people were deterred by the distance to the restoration site due to physical mobility constraints. Gender equity (mean rank = 3.7 of 12) and age equity (mean rank = 1.6 of 12) issues were considered comparatively less important than procedural equity issues (Fig. 3). The key informant interviews suggested that the gender imbalance in employment (ratio of women to men, 1:1.8) was not viewed as a significant inequity, even by women, because of traditional gender roles.

However, the key informants unanimously maintained that employment of women led to greater benefits to families, children in particular, as women tend to spend their income on commodities that benefit the family (e.g. food), while men often spend their income on alcohol and drugs. This led to greater intergenerational equity (benefit-sharing within families) and, to the extent that employed women were from poorer families,

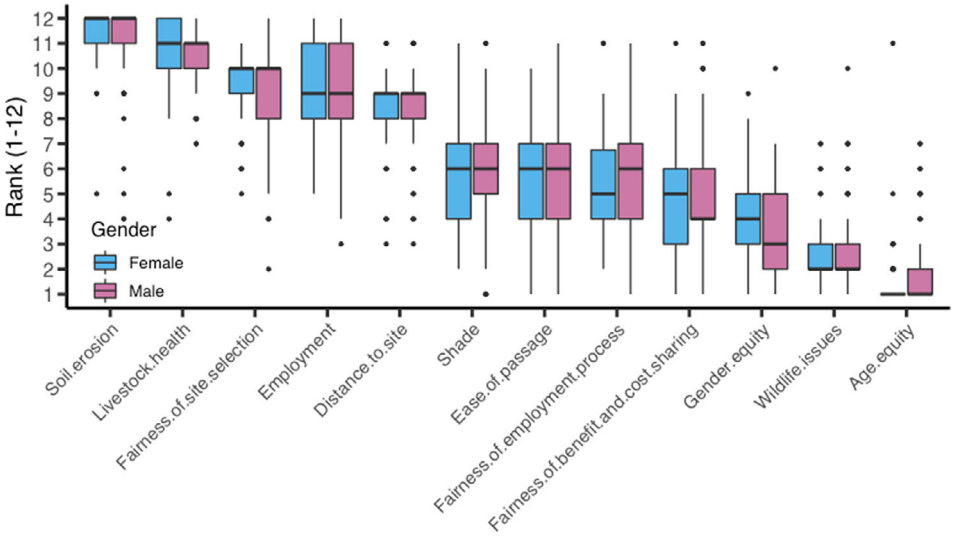
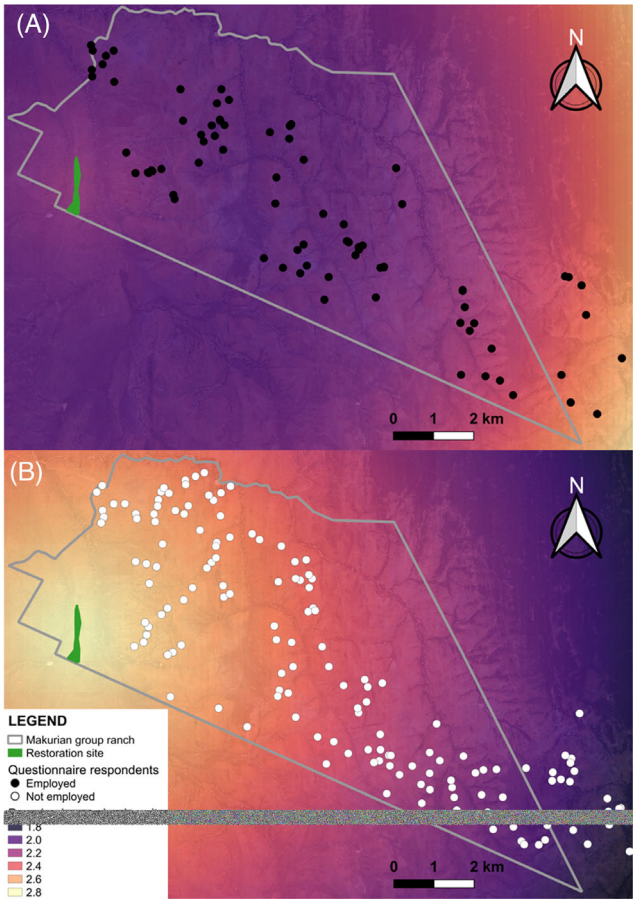


Figure 3. Priority ranking of issues covered in the questionnaires (lowest = 1, highest = 12) by gender (female, $n = 82$; male, $n = 150$).

to greater equity among families. The two female key informants suggested that women would also perform restoration work more effectively and should be prioritized for employment. The community leader commented: "I have seen women are the best casual workers and also the money they get from working reaches the children." The local government official stated: "a lot of times I am working with women, I have a better workforce in women than men—I don't know, I could be biased."

Procedural Equity

One of the main elements of positive feedback on the project from the key informant interviews was for providing employment to all clusters, because many development projects only work with and benefit individual clusters. One community leader mentioned "There are NGOs who are only creating conflict within the community by engaging only one cluster." The mean perceived procedural equity was 4.1 of 5 for fairness of employment process and 2.3 of 5 for fairness of site selection. The priority ranking exercise showed that aspects of procedural equity (fairness of site selection, mean rank = 9.1 of 12) were perceived to be more important than aspects of distributive equity (fairness of cost and benefit sharing, mean rank = 4.8 of 12; Fig. 3). Perceived fairness of the employment process was 5% greater for those employed than respondents not employed ($F = 27.0$, $p < 0.001$) and, among those employed, increased 10% with every 10 km from the restoration site (employed: $F = 3.4$, $p = 0.07$, not employed: $F = 0.7$, $p = 0.41$). Perceived fairness of the restoration site selection process was 12% lower for those employed than respondents not employed ($F = 8.1$, $p = 0.004$) and decreased 25% with every 10 km from restoration site ($F = 5.8$, $p = 0.02$) and among respondents not employed by the project ($F = 17.0$, $p < 0.001$), but increased nonlinearly with distance from restoration site among those employed (second degree polynomial, $F = 3.6$, $p = 0.03$; Figs. 4 and S2). The cluster most frequently proposed for future restoration work (40% of respondents) was also one of the most central (reducing distance to restoration site) and had the third highest *O. stricta* prevalence of all clusters (Fig. 5).



Recognitional Equity

The process of employment and restoration site selection also involves recognitional equity, in particular between project implementors and community members. The community's sociocultural norms and traditional decision-making processes were respected by not imposing rules, such as setting employment quotas for clusters, gender, and/or age group. The values of community members were also respected in deciding on the restoration approach and setting of restoration goals. For example, community members were employed (as opposed to volunteering) as per the community's request, showing that they valued employment to an extent that outweighed the risk of crowding out and hindering the sustainability of restoration activities (valued by the project coordinators). Regarding restoration goals, the community decided to fill gullies with uprooted *O. stricta* plants in some areas, because cacti establishing there would reduce soil erosion—a high-priority issue (mean rank = 11.4 of 12). Participant observation during the restoration work revealed that community members felt that filling gullies with uprooted *O. stricta* plants was ethically sound, despite admitting the heightened risk of cladodes (flat stems) establishing in communities downstream. Recognizing and endorsing this ethical position would create inequity for downstream communities, which exemplifies equity trade-offs across social scales. As a compromise, the community decided, under no pressure from the project leaders, to fill only small gullies in areas with little run-off and thus reduced risk of cacti washing into seasonal rivers.

Theoretical Equity-Restoration Relationship

We use our empirical data to build on research from the literature search to construct a hypothetical relationship between equity and the degree to which restoration outcomes are met

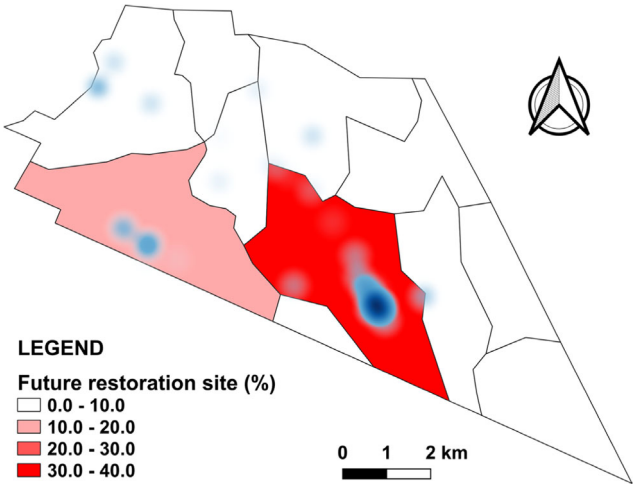


Figure 5. Proposed future restoration sites. Heatmap (blue) shows point density of proposed sites and the shading (red) illustrates the proportion of respondents proposing the future site should be in a particular cluster. The central location of the future site proposed by the majority of respondents highlights the importance of distance to the restoration site.

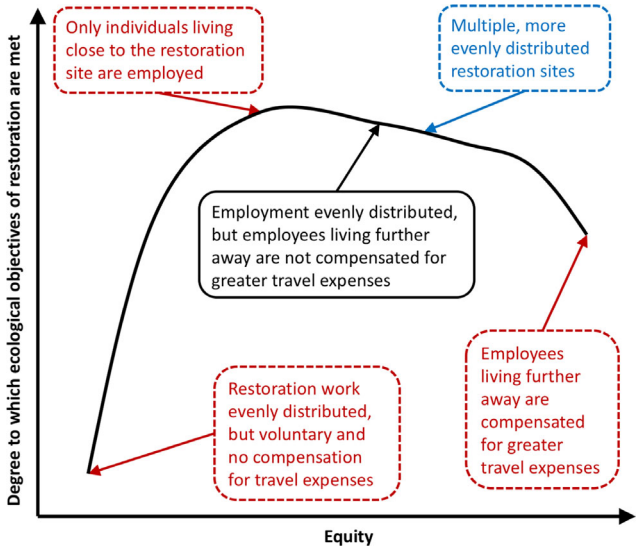


Figure 6. Hypothetical relationship between equity and the degree to which ecological objectives of restoration are met. Potential alternatives to the approach taken in this project (black) that would be more (blue) or less (red) optimal regarding restoration and/or equity objectives are highlighted. Adapted from Halpern et al. (2013).

(Fig. 6). It includes potential outcomes of alternative approaches to the restoration project suggested in key informant interviews. For example, the suggestion from two key informants of organizing multiple clearing events across Makurian would also increase employment of women, who were deterred by the distance to the restoration site and associated transport costs, time, and risk of encounters with elephants. One key informant commented: "Most of the women had a problem because of the distance to the site—also fear of elephants when it is dark […] Maybe you can organize so that people do [restoration] work in their respective areas." This approach of smaller but more evenly distributed restoration sites may have increased perceived equity with little change to meeting certain restoration objectives (specifically, total area cleared). However, smaller cleared areas may be more rapidly recolonized by *O. stricta* due to greater edge effects, thus diminishing restoration effectiveness and sustainability. A limitation of this hypothetical relationship between equity and the degree to which restoration outcomes are met (Fig. 6) is its simplistic representation of two multidimensional variables. However, we believe that it provides a useful heuristic.

Discussion

All four dimensions of equity played a role in this ecosystem restoration project. Employment and distance were key correlates of perceived equity (particularly distributional and procedural equity) and sometimes interacted. Our spatially explicit analysis of perceived distributional and procedural equity shows that the effects of distance can be nonlinear and counterintuitive. Employment appeared to have a negative effect on perceived fairness of restoration site selection among those living closer to the site. This surprising result may be because the influx of herders and their livestock from further afield attracted by and utilizing the restoration site (evidenced by dung surveys and key informant interviews) triggered resentment in people living closer to the site. This resentment for "free-riders" was more prominent for employees, who invested time and energy in restoring the area, which outweighed their perceived benefits of employment. Alternatively, among those living close to the restoration site, nonemployed individuals may have felt that they particularly benefited because they avoided the physical labor associated with the restoration work. Both of these effects may have occurred simultaneously to produce the observed patterns, but both highlight that investment of time and energy may outweigh monetary benefits in determining aspects of perceived equity, even in poor communities. The concept of "spatial justice" has been applied in urban areas (Soja 2008; Schell et al. 2020) and there is a growing interest in "pixelizing the social" and mapping social values (Liverman et al. 1998; Nahuelhual et al. 2016), but the use of geographic information systems in equity studies is rare (Friedman et al. 2018). Our results also echo other work (McDermott et al. 2013; Martin et al. 2016) emphasizing the importance of moving beyond distributional and procedural equity to consider the contextual and recognitional dimensions of equity that influence restoration work.

Regarding contextual equity, the role of historical injustices in the need for restoration was not raised during the key informant interviews, which may be due to the positionality of H.B. M.W. and C.L.C., both of whom are white Kenyan descendants of British colonial settlers. By studying colonial history, particularly of Laikipia, we strived to mitigate what McIntosh (2016) calls "structural oblivion"—a state of ignorance, denial, and ideological myopia that emerges from an elite social structural position. However, respondents may have, consciously or not, avoided the topic of colonialism for fear of triggering the shame

and anxiety associated with a form of moral "double consciousness"—the "sense of always looking at one's self through the eyes of others, of measuring one's soul by the tape of a world that looks on in amused contempt and pity" (DuBois 1996)—as experienced by white Kenyans (McIntosh 2016). The influence of positionality should be reflected upon when analyzing social data.

Regarding recognitional equity, respecting different values and social norms necessitates the appreciation and celebration of the plurality of ethical frameworks (Schlosberg 2013; Sikor et al. 2014; Law et al. 2017). Our results exemplify that this diversity of values systems can lead to trade-offs between conflicting ethical positions. Trade-offs between equity objectives of different actors at different scales (e.g. between focal and downstream communities—and project coordinators—regarding filling gullies with *O. stricta*), mirrors similar issues for ecological objectives of restoration (Brancalion & Holl 2020). The dominant form of equity in international discourses is structured by a utilitarian ethical framework, focusing on the distributional dimension of equity, contemporary individuals as the "justice subjects" (the stakeholders considered), and merit—as opposed to equality, need, or deservedness—as the "criterion" or decision-making guideline that organizes relationships between justice subjects. It may not necessarily be appropriate to impose this dominant form of equity in the Global South (Sikor et al. 2014). Using the example of this study, one cluster was given fewer employment opportunities because it had an active development project providing jobs clearing *O. stricta* (i.e. emphasizing needs over merit as the equity criterion). Prioritization of poorer families provides a similar example.

Although we did not explicitly evaluate the role of power dynamics, the balance of power between project leaders and community members and among community members is likely to have influenced perceptions of equity. For example, despite clear communication from the project leaders to community members that they were merely facilitating the project, aspects of their positionality (e.g. education) may have led to unconsciously perceived authority of the project leaders over community members. The power structures within the community also determine collective decision-making. The considerable distance between the chosen restoration site and the location of the future restoration site most frequently proposed by respondents suggests that these power dynamics influenced the restoration site selection.

Our results also highlight that different dimensions of equity are intimately linked. For example, the respect for socio-cultural norms (recognitional equity) during the employment process influenced the perceived fairness of the employment process (procedural equity), which, in turn, affected the perceived fairness of cost and benefit sharing (distributional equity), because employment played a key role in perceived benefits. In this study, trade-offs occurred between equity dimensions. For example, asking community members to propose the next restoration site may appear to some to be a more democratic process than allowing community leaders to make this decision, increasing procedural and distributional equity. However, over a quarter of respondents answered "anywhere" and only 40% suggested a specific location, which suggests indifference. More importantly, this would undermine traditional decision-making processes, reducing recognitional equity.

Different aspects of equity, such as gender and age equity, can interact in a way that the level of marginalization experienced is more than the sum of marginalization along each axis, termed "intersectionality" (Lau 2020). Although we did not explore intersectionality in this study, awareness of its effects may aid in meeting equity objectives in restoration. Although incorporating equity into ecosystem restoration will add an extra level of complexity and cost, we opine that it will lead to more effective, efficient, and successful restoration work. The validity of this proposition should be investigated in future research by comparing similar restoration projects with differing degrees of equity, ensuring that diverse dimensions of equity and restoration success are considered.

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Conflict of Interest

The authors declare no conflicts of interest.

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Supporting Information

The following information may be found in the online version of this article:

Supplement S1. Questionnaire.

Supplement S2. Positionality statements.

Table S1. Livestock relative values used for individual and household wealth metric.

Figure S1. *Opuntia stricta* occurrence probability in Laikipia and Samburu counties.

Figure S2. Interactions between distance to restoration site and employment in their relationship with perceived procedural equity of restoration site selection.

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