LETTER

Effects of a grazing permit market on pastoralist behavior and overgrazing in Kenya

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Abstract

The success of market-based mechanisms in reducing conflicts and internalizing externalities depends on their ability to clarify property rights amongst heterogenous resource users. We investigate the effectiveness of novel markets in achieving their goals using the case study of grazing markets in Laikipia County, Kenya. In this system, sheep- and goat (shoat)- and cattle-rearing pastoralists negotiate land access for cattle with neighboring cattle ranchers. Using data on pastoralists’ livestock and contracting preferences and a model of pastoral herd management, we show that contracting for cattle grazing access on private property alters relative input shadow prices for grazing resources in communal pastoral lands, ultimately resulting in relieved cattle grazing pressure. However, the permitting process is less attractive to pastoralists who prefer rearing shoats instead of cattle. These shoat-rearing pastoralists instead fill some of the vacated space with shoats instead of purchasing permits themselves. This leakage offsets some of the conservation benefits arising from the contracting program and results in a greater share of shoats in the communal herd mix. Approximately 0.59 cows’ worth of free space persists on the commons per permit sold, indicating reduced grazing pressure, but this represents a small proportion (3.8%) of the total livestock in the system. The narrow introduction of the cattle-focused permit market and lack of strong management institutions on the commons dampen the permitting program’s conservation benefits, necessitating further interventions. Alleviating these factors and dramatically scaling up the program has the potential to turn the permitting system into a successful conservation tool.

Market-based institutional reforms often appeal to policymakers seeking to resolve conflicts over natural resources and improve welfare. Such policies form the backbone of empirical applications of the Coase theorem, which demonstrates that the efficiency of economic allocations between parties is independent of the initial resource allocation when transaction costs are low (Coase 1960, Dorius 1993, Deininger 1999, Yung and Belsky 2007). Possible mechanisms for market-based conflict resolution include land markets, property rights reform, and compensation for damages (Fratkin 2001, Kinzig et al 2011, Lewis 2015, Barrios et al 2016, Salzman et al 2018). Market-based approaches are often proposed as a solution to social or environmental problems, but in practice the markets may be narrowly introduced or fail to capture important agents.

Regulating firms by creating voluntary markets for pollution permits may lead to concerns about permanence, leakage, and additionality (‘PLA’) that undermine the effectiveness of the intervention in resolving externalities. PLA concerns create a tradeoff for policymakers, who risk scaring off high-polluting firms if market prices are too high, but risk efficiency losses and non-additionality if prices are too low (Millard-Ball 2013). This challenge is well-studied in the context of pollution permits and carbon offsets, where PLA concerns and adverse selection may
significantly undermine the benefits of voluntary pollution control policy, even if the result is still net-positive for society (Montero 1999, Millard-Ball 2013, Bento et al 2015). PLA concerns are less well-studied for other environmental markets.

We use the case study of novel grazing markets in Laikipia County, central Kenya, to investigate how PLA concerns may complicate environmental markets. Laikipia is a semi-arid rural county characterized by high livestock densities alongside high biodiversity. Laikipia boasts the second highest abundance of wildlife in East Africa, after the Mara-Serengeti ecosystem (Sundaresan and Riginos 2010). Laikipia also supports the largest population of endangered megafauna in Kenya and has the largest diversity of large mammals of any region its size in the world (Butynski and Jong 2014, Witt et al 2020). The county exists as a mosaic of land parcels, with about 30 private ranchers controlling half the land area and most of the rest existing as a combination of smallholder farmland, communally-managed pastoralist group ranches, and unmanaged land owned by absentee landlords. Droughts are common in Laikipia and often lead to land use conflict as different actors compete for scarce resources (Fox 2018).

We consider two major land users: pastoralists and ranchers. Both are livestock herders. After a complicated history of colonization, treaties, and land tenure reforms, pastoralists are largely confined to communally-managed ‘group ranches’, which are de facto ‘commons’ and perennially overgrazed by livestock (Fratkin 2001, Desta and Coppock 2004, Boles et al 2019). This overgrazing results in reduced vegetation cover (among other issues) and has driven declines in wildlife populations on group ranches, as observed across Kenya (Ogutu et al 2016). Ranchers manage properties similar in area to the communal lands, but private property rights enable excludability. Private ranches often double as wildlife conservancies, stocking livestock at densities 3.5 times lower than pastoralists do (Odadi et al 2011). This results in higher quality and more abundant grass on private ranches than on the commons, driving conflicts over grazing access that flare up when droughts or other disturbances make grazing resources more scarce (Bond 2014). In these tense periods, some pastoralists illegally move livestock onto private ranches, which can escalate into violence (Burke 2017, Leithead 2017, Fox 2018, Boles et al 2019). The conflicts are sometimes driven by pastoralists from outside Laikipia, who bring their herds through the county when droughts render neighboring counties unsuitable for livestock, affecting both types of local land users. This drove a particularly violent set of conflicts in 2017 (Burke 2017, Leithead 2017). Therefore, ranchers incur large costs to enforce their property rights, for example by hiring and arming guards.

In response to these conflicts, pastoralists and ranchers created a system of cattle grazing permits allowing pastoralists to graze their cattle legally on private ranches in exchange for a monthly per-head fee. Pastoralists are not required to purchase permits unless they wish to graze their cattle on private ranches, and grazing activity on communal pastoral lands remains unrestricted. In most cases, the total number of permits is set by the rancher and sold in aggregate to the neighboring pastoral community, who decide how to allocate the permits amongst themselves. In other cases, ranchers have established relationships with a select number of (generally wealthy and influential) pastoralists and sell permits specifically to them. The terms of the grazing permits vary widely, with some ranchers offering herding labor, metal ‘predator free’ enclosures, and tick repellant. The grazing permits only apply to cattle, so other important forms of livestock, such as sheep and goats (‘shoats’), must remain on the communal pastures.

Shoats are increasingly important in Laikipia because of their high fecundity, their ability to subsist on degraded landscapes, and the relative ease with which herders can sell them. Still, cattle remain culturally important for East African pastoralists, who use cattle as bride price and measures of wealth (McCabe 1997, Osterle 2008, Huho, Ngaira and Ogindo 2011). Although five shoats are considered equivalent to one head of cattle using the common tropical livestock unit (TLU) measure, this shift to shoats brings large changes to the landscape. Goats share cattle’s preference for high-quality forage, can graze for longer periods without water than cattle, and are able to eat woody stems and shrubbery that cattle do not eat (Steinfeld et al 2006, Hart 2008). Sheep graze similar plant species to cattle but leave less vegetation cover behind, due to their small mouths and resulting ability to clip grass closer to the soil than cattle. At the high stocking densities present on pastoral lands, shoats have large impacts on the ecosystem and their heavy grazing can reduce available forage for wildlife such as the endangered Grevy’s zebra (Equus grevyi) (Peacock and Sherman 2010, Rosa García et al 2012). This is part of the reason private ranches exclude shoats from the permitting system.

Aside from the goal of reducing conflict, the permitting system intends to ease grazing pressure on the commons by offering pastoralists alternative grazing patches. This conservation goal is complicated by the non-excludability of pastoral lands. Pastoralists who are committed to increasing their cattle herds

5 1 TLU equals one head of cattle or five shoats. One shoat is therefore equal to 0.2 TLU.

6 In this article we use the term ‘grazing pressure’ to reflect the intensity of livestock grazing, correlating with stocking densities. High grazing pressure stresses grass resources, while low grazing pressure relaxes grass resources and makes them available for wildlife.
have strong incentives to purchase grazing permits and move cattle to private ranches. Conversely, pastoralists who prefer to rear shoats have little reason to spend money on cattle grazing permits instead of expanding their shoat herds for free on the commons as it becomes less heavily grazed by cattle. This sets up a potential leakage, posing a threat to the success of grazing permits in promoting conservation on the commons.

Laikipia is an ideal setting to study the ecological effects of these market-based mechanisms because few other places in Africa have such a widespread program of leased grazing. Furthermore, Laikipia’s permitting system has been proposed as a model for other regions (Regional Pastoral Livelihoods Resilience Project 2020). Here, we study the effects of the permitting system on pastoralists’ livestock rearing decisions and investigate whether permits relieve grazing pressure on communal lands. Our model is rooted in pastoral culture and the results are contextualized with Laikipia’s history of resource conflict. Using economic theory and data from 301 household surveys, we develop empirical methods to explain how heterogeneity in the use of the commons may complicate conservation policies and lead to PLA concerns.

1. Theory

An “indifference curve” traces out the combinations of shoats and cattle that make pastoralists equally well off. Pastoralists’ shoat-cattle indifference curves enable evaluation of the effect of permit price on their chosen livestock bundle (see appendix A for derivation). We model grazing permits as a decrease in the implicit (shadow) input price of cattle for pastoralists who purchase the permits (‘ranch-users’). The permit system is expected to reduce the input shadow price of cattle because permits increase aggregate grazing area, reduce biological constraints on cattle production, and make cattle easier to rear. After ranch-using pastoralists move animals to ranches, any leftover space on the commons is accessible to the remaining pastoralists. This implicitly increases the non-ranch-using pastoralists’ income as well (by reducing scarcity in the commons and decreasing the shadow price of communal grass), allowing them to also rebalance their shoat-cattle bundles.

1.1. Ranch users

Ranchers set the quantity of permits sold to allow them to maintain space on their ranch for wildlife and their own cattle. At this quantity, the observed permit price must be no lower than ranchers’ marginal opportunity cost and no higher than pastoralists’ marginal demand. The efficient market-clearing equilibrium exists where both hold as equalities—the intersection of supply and demand. Because quantity remains fixed by ranchers, any deviation from the market-clearing price generates a transfer of economic surplus from one agent to the other.

Since grazing permits are currently widespread in Laikipia, we use pastoralists’ observed herds as a baseline to compare to a counterfactual where no permits are offered. We obtain each pastoralist’s observed surplus by calculating their share of the total consumer surplus in the market. We express this cash value in terms of grazing permits by dividing by the current market price and subtract it from the cattle-intercept of the current budget constraint (the dotted lines in figure 1) to rotate the constraint inwards.

This simulates an increase to the choke price, where quantity demanded is zero (the y-intercept), effectively modeling a scenario without the permit market (the solid lines in figure 1). The slope of this new, steeper budget constraint is used to identify a tangency with a lower indifference curve, yielding the optimal bundle of shoats and cattle under the no-permits scenario.

We also compute the marginal impact of grazing permits. To do this, we use the simulated no-permits scenario as a new baseline and add the consumer surplus associated with one grazing permit to each ranch-user’s cattle-intercept following the same process as above. See appendix A for the derivations associated with this rotation of the budget constraints. Our analytical process, visualized in figure 1, assumes it is costless to obtain new animals and that grass availability is the only constraint on cattle production that is affected by grazing permits. These assumptions are reasonable in Laikipia, where new animals are generally bred instead of purchased and herding labor is largely fixed.

7 For example, a price lower than the market-clearing price constitutes a transfer of economic surplus from ranchers to pastoralists in the form of a discount on permits.
1.2. Non-ranch-users

After ranch-users move cattle to private ranches, they leave free space behind on the communal lands. This gives other pastoralists who do not purchase permits (‘non-ranch-users’) an opportunity to expand their herds to fill the space. The freed space thus provides an implicit income bump for non-ranch-users. In the same way that permits make cattle easier to rear for ranch-users—by reducing biological constraints on production—the extra grass on the commons makes both forms of livestock easier to rear for non-ranch-users.

For every TLU of freed commons space, non-ranch-users’ shoat-intercept increases by five and their cattle-intercept increases by one\(^8\). Graphically, this is a shift in the budget constraint as opposed to a rotation (figure 2). Because there are many more non-ranch-users than ranch-users, each non-ranch-user’s income increase only reflects a fraction of the total freed space. We scale the freed space by the ratio of ranch-users to non-ranch-users when computing the change in implicit income.

To calculate new optimal livestock bundles, we follow the same analytical process used for ranch-users, summarized in appendix A. We do the same to evaluate the marginal impact of the permits. All the curves are calibrated using empirical data (see the Supplementary Material for the script used in data analysis available online at stacks.iop.org/ERL/17/035002/mmedia).

2. Data collection

We surveyed pastoralists living in Laikipia County\(^9\) (figure 3) to collect information about their livestock production preferences and responses to grazing permits. Many sections of the survey ask about past and current decisions, while others rely on stated preference or behavior. We follow the recommendations of Johnston et al (2017) as much as local circumstances permitted, including qualitative pre-testing, tailoring questions to reduce cognitive burden, thoughtfully deciding between willingness-to-pay and willingness-to-accept, and allowing respondents time to think through their responses.

To inform survey design, we conducted semi-structured interviews with pastoralists and ranchers to learn contextual information that also aids interpretation of the results. To refine the survey and add clarifying information, the survey was piloted with pastoralists living in the same villages as the ones we ultimately sampled. An English-language version of the questionnaire is shown in appendix B\(^10\).

The survey was administered in July and August of 2019, during a wet period in central Kenya\(^11\). 301 total responses were collected. Study villages were chosen to represent a large geographic spread across Laikipia (figure 3). Because our goal was to study the effects of grazing permits on pastoral behavior, all villages surveyed had some formal permit marketplace with a nearby ranch, with some of the most heavily surveyed villages having the most universal access to permits. These heavily surveyed villages were also the most accessible by road. Within each village, manyattas (family housing clusters) and village centers were sampled randomly. At each site, every adult present was interviewed.

To incentivize participation in the survey, each interview included an Eckel-Grossman risk game (Eckel and Grossman 2002, Dave et al 2010), where respondents bet on the outcome of a dice roll and received up to 135 ksh\(^12\) depending on the result\(^13\). In general, we found respondents to be very risk averse. Approximately 58% of our sample is composed of women, partially because we surveyed most pastoralists living in the same villages as the ones we ultimately sampled. An English-language version of the questionnaire is shown in appendix B.

A local Maasai enumerator presented the questionnaire on a tablet in Kiswahili and read it verbally in Maa, the native language of most of the Laikipia pastoral community. Respondents who did not speak Maa had their interviews conducted in Kiswahili. Because our aim was to understand pastoral behavior,

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\(^8\) This reflects the TLU ratio of shoats to cattle (5:1) and contrasts with the ranch-users, for whom the cattle-intercept changes but the shoat-intercept stays fixed.

\(^9\) With the exception of seven respondents from neighboring Isiolo County, who were included because they have access to grazing permits offered by ranchers in Laikipia. The incentive structures of their pastoral lands are the same as Laikipia residents’.

\(^10\) Many questions present in the survey were not used for the analyses in this paper.

\(^11\) The high rainfall could reduce demand for grazing permits overall and lower respondents’ willingness-to-pay, but this is true of the entire sample and does not impact our calculation of livestock preference parameters, which are the fundamental inputs to our model.

\(^12\) Kenyan shillings, approximately 100 ksh per $1 USD.

\(^13\) The results of the Eckel-Grossman game are used in a different study.
we did not formally survey ranchers, though they participated in qualitative interviews.

3. Results

3.1. First-order effects: ranch-users
Pastoralists pay well below market price for permits (figure 4)\(^14\). There are 54 ranch-users in the sample who collectively purchased 979 permits at an average market rate of 450 ksh/head/month ($4.50). By calculating the aggregate demand curve in our sample and intersecting it with the fixed supply of permits, we estimate that the market-clearing price for grazing permits is 762 ksh/head/month ($7.62). This disparity transfers an economic surplus from ranchers to pastoralists equal to 5662 ksh/head/month ($56.62)\(^15\). This is paid by all ranchers collectively to each ranch-user. Given current contract prices, this transfer is borne by pastoralists as an average of 12.58 ‘free’ contracted cattle per ranch-using pastoralist.

Our modeling suggests that pastoralists use this transfer to expand their cattle herds and increase their ratio of cattle to shoats, as seen in table 1. When permits are not offered, current ranch-users are expected to keep a median herd size of 26.62 TLU. This increases to 32 TLU when permits are introduced.

To analyze the ecological impacts of pastoralists’ decisions, we express the livestock changes in TLUs, where five shoats are equivalent to one head of cattle. When permits are not offered, current ranch-users are expected to keep a median herd size of 26.62 TLU. This increases to 32 TLU when permits are introduced.

These TLU increases are offset when animals are moved to private ranches, dividing grazing pressure between ranches and the commons. The median herd size kept on the commons by current ranch-users is expected to be 26.62 TLU with no permits in place and is 20.00 TLU with permits. This implies the commons see less grazing pressure from ranch-users after permits are purchased.

3.2. Indirect effects: non-ranch-users
Non-ranch-users are expected to keep a median of 35.12 TLU of livestock without a permit market and 30.00 TLU with a permit market. Much of this drop in TLUs comes from a switch that non-ranch-users make towards rearing shoats. When there are no permits, the median cattle/shoat ratio for non-ranch-users is modeled to be 0.31. This drops to a median of 0.23 when ranch-users receive the permits.

Herd expansion by non-ranch-users encroaches on much of the freed space that ranch-users leave behind. Each ranch-user is expected to leave a median of 4.01 TLU of free space when permits are offered. Non-ranch-users collectively fill over half of this free space. This equates to a net reduction 1.79 TLU of commons grazing pressure per ranch-user—just under two cows.

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\(^14\) In economic terms, the ranchers are imposing a voluntary price ceiling on themselves, which is efficient as long as it is less than or equal to the cost of property rights enforcement or violent conflicts if negotiations fall apart.

\(^15\) This is the area of the shaded rectangle in figure 4.
Figure 4. Market supply (theorized) and demand curves with visualization of self-imposed price ceiling.

Table 1. Livestock bundles under certain market conditions.

|                | Ranch-users | Non-ranch-users |
|----------------|-------------|-----------------|
|                | No. cattle  | No. shoats | Cattle/shoat ratio | Total TLU | Commons TLU | No. cattle | No. shoats | Cattle/shoat ratio | TLU |
| No permits     | 7.64        | 67.85       | 0.08             | 26.62      | 26.62       | 20.48      | 55.75       | 0.31             | 35.12 |
| Permits        | 15.00       | 60.00       | 0.23             | 32.00      | 20.00       | 13.00      | 60.00       | 0.23             | 30.00 |

Note: All reported numbers are the median for the sub-sample. It is a coincidence that ranch-users and non-ranch-users have equal median cattle/shoat ratios with permits in place.

3.3. Marginal impact of grazing permits

To contextualize the results from this analysis, we multiplied the marginal effect of permits by the total number of permits sold in our sample. This gives us a rough practical sense of the effects of the permitting program on conservation, assuming the marginal effects scale linearly.

For every permit sold, ranchers leave behind approximately 1.33 TLU of free space. The extra 0.33 TLU of freed space could arise from many factors not explained by our model. Non-ranch-users collectively fill around half of this freed space, such that for every permit sold, there is a 0.59 TLU net reduction in grazing pressure on the commons. This equates to 576 TLU of reduced grazing pressure on the commons when scaled to the level of the sample. All pastoralists in the sample collectively own 15,037.2 TLU of livestock, meaning the reduction in grazing pressure accounts for approximately 3.8% of the total pastoral livestock population.

3.4. Caveats

These numbers underestimate the degree that leakages dampen the conservation benefits. At the population level, there is greater competition for space left behind by ranch-users. Most of this dataset comes from villages with high ranch access, whereas most other communities in Laikipia have less universal access. Our modeling also does not account for leakages arising from pastoralists outside the system moving into Laikipia to graze their animals after ranch-users leave behind free space. This adds to the second-order effects described in this section and puts further pressure on already stressed resources (Burke 2017, Leithead 2017, Fox 2018). The only (non-ecological) limit to this leakage is the ability of the resident pastoral community to enforce their property rights, often through force since formal legal institutions are nonexistent. Our interviews suggest that these leakages are driven in part by a perception that communal rangelands in Laikipia are awash with free grazing area after ranch-users move their cattle away. Qualitative data in our survey support this, with 82% of respondents (Laikipia residents) stating that they expect others to expand onto the freed grass left behind after cattle move onto private ranches. However, we did not survey pastoralists from outside Laikipia, so our study...
cannot estimate the magnitude of the additional leakage.

The ecological underpinnings of this analysis also underestimate the effect of non-ranch-users and pastoralists from outside Laikipia, since our use of TLU does not account for the differences in grazing/forage behavior that make the ecological consequences of mixed shoat herds much different than cattle (Steinfeld et al. 2006, Hart 2008). The analysis ignores changes in the number of camels, donkeys, or other livestock pastoralists may rear. Our estimate of 1.79 TLU of freed space per ranch-user, and 0.59 TLU of freed space per permit, should thus be considered an upper-bound.

4. Discussion

4.1. Conservation outcomes

The overall effect of the permitting system on commons conservation is small, but positive. After ranch-using pastoralists move cattle off the commons, pastoralists who do not purchase permits expand their own shoat herds to fill some of the empty space. This alters the aggregate herd mix on the commons in favor of shoats. While we find some benefits from the permitting system in curbing overgrazing, they should be appreciated in the context of these herd mix changes and the sheer number of livestock currently owned by pastoralists in Laikipia.

A 3.8% reduction in grazing pressure does little to promote wildlife habitat. Consider that the 576 TLU total reduction in grazing pressure we estimate equates to approximately 720 zebras distributed across Laikipia\(^1\). With a total Laikipia zebra population around 30 000 (Georgiadis et al. 2011), 720 animals is a positive but low proportion of the total population. Also, in reality zebras must also compete for space with other wildlife and cattle moving in from outside Laikipia, factors not included in our model. Finally, recall that private ranchers in Laikipia generally stock livestock at less than 1/3 the density that pastoralists do. This implies that, assuming constant abiotic conditions, pastoralists would need to reduce their herds by over 2/3 (67%) to produce a landscape that looks similar to private ranches. While such an extreme reduction in herds may be more than is necessary to achieve conservation goals\(^1\), it demonstrates that the 3.8% reduction due to permits is very small compared to the standard set by ranches in the area.

The TLU reductions also do not account for differences in the ecology of the commons due to the new herd mix. The ‘new’ commons after permits are established contains a higher proportion of shoats, reducing the availability of browse compared to when those TLU were composed of cattle. This is troublesome for browsing wildlife species.

These ecological changes arise from exclusion of shoats from the permitting system, which creates incentives for many pastoralists to opt out of the permit market and flood the commons with shoats. This leakage demonstrates a complication seldom discussed in canonical models—the marginal entrant may have a different impact on the resource than the average user. If institutions reduce the average user’s activity, marginal users can expand and impact the landscape in unforeseen ways. This has implications on the permitting system’s ability to allay PLA concerns. While our results do not comment on additionality, they present a clear leakage via the indirect effects, and this leakage threatens the permanence of conservation benefits that arise from the ranch-users’ reduced grazing pressure. However, the leakage is small enough that it still allows for some conservation benefits.

4.2. Conflict outcomes

Grazing permits are generally not offered to pastoralists who live outside Laikipia. This is a consequential omission, considering one major impetus for the permitting system is the conflict that results from these pastoralists moving into Laikipia from outside the system. However, our interviews indicate that lingering distrust between Laikipia Maasai and pastoralists from other tribes outside of the county make it risky for ranchers to develop strong relationships with these ‘outsiders’. Ranchers risk alienating their Maasai neighbors if they provide permits to herders from outside the county, so they instead leverage strong partnerships with these neighbors to help defend against trespassing by the outsiders.

This dynamic motivates a secondary finding of this study: ranch-using pastoralists are able to use the permit market to extract economic rents from ranchers by leveraging the threats of violence and illegal grazing. Ranchers rely on ranch-users to help police their communities for illegal grazing and serve as the first line of defense if others move in from outside the system. This conciliatory dynamic is dependent on the goodwill extended by ranchers in the form of cheap permits, creating a mechanism for ranch-users to continue demanding below-market prices\(^1\). The arrangement represents a unique ability for pastoralists to exercise greater market power in a system

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\(^{16}\) Assuming one zebra = 0.8 TLU. This is a reasonable estimate given that donkeys (0.7 TLU) are often used as surrogate zebras in the planned grazing literature (as in Odadi et al. 2011).

\(^{17}\) Emulating private ranches is not necessarily a policy goal and the comparison is made here merely as a heuristic. Thus, it may not be necessary to reduce herds by the full 67% that would roughly equate pastoralists with ranchers. However, ranches provide a useful point of comparison due to their ability to host large resident wildlife populations.

\(^{18}\) This arrangement is still economically efficient as long as the profit losses to the ranchers are less than or equal to the cost of hiring extra guards to enforce their borders or being subject to violence.
with no regulatory oversight and violent unrest in its recent history.

Another unintended consequence of the permitting system is persistent inequality. Qualitatively, wealthy pastoralists generally have better access to grazing patches on private ranches and are more likely to be ranch-users (Hauck and Rubenstein 2017). While the permitting system benefits non-ranch-users through relieved cattle pressure, the benefits of the program appear to accrue disproportionately to ranch-users since they additionally receive economic surplus from ranchers (increasing their welfare). The larger per-TLU economic value of cattle compared to shoots also means pastoralists dependent on shoots receive smaller economic returns from increasing their herds. Thus, while the permit system appears to increase welfare for all, it does so unequally, which carries its own potential for intra-community conflict.

4.3. Takeaways
All of the dynamics described in this article play out over a long-term equilibrium, where pastoralists have time to grow their herds and encroach on freed space. However, in practice, semi-arid ecosystems in East Africa rarely reach equilibrium due to regular drought shocks (Ellis and Swift 1988). These droughts dampen the second-order effects described in this article by periodically devastating livestock herds or inducing pastoralists to sell off their small stock, ironically making droughts positive for wildlife due to reduced competition with livestock. However, the status quo of intensive land use by pastoralists keeps wildlife away from the commons for much of the year. Thus, the grazing permits alone are not a reliable tool to promote conservation and rehabilitate wildlife habitat, and should be paired with practices such as planned grazing that have been demonstrated to improve conservation outcomes on pastoral lands (Odadi et al 2017, Crawford et al 2019).

If the program were able to significantly expand in size and scope, the small marginal improvements could translate into large conservation gains. Exactly how much the program needs to expand depends on the goals of decision-makers and stakeholders, but any expansion should include shoots and be accompanied by improved management institutions that enable excludability on the commons or implement planned grazing. These changes would help close the leakages driving PLA concerns and improve the conservation outcomes of the program.

However, selling more permits would cut into ranchers’ grass bank and ranchers are not currently interested in offering permits for shoots, making it unlikely that ranchers would support the large expansions of the permitting program necessary to recover wildlife populations. Resolving this tension is an important intervention for local planners interested in making the permitting system successful. Still, this novel market has given ranchers and their pastoral neighbors a reason to work together and resolve their differences while modestly improving the quality of the pastoral rangeland.

Data availability statement
The data generated and/or analyzed during the current study are not publicly available for legal/ethical reasons but are available from the corresponding author on reasonable request.

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Ethical statement
This study was granted a waiver of approval by the Yale University Institutional Review Board under Protocol ID 2000026182. No identifying information was collected from respondents and the exemption was granted under 45CFR46.104 (2)(ii). Consent was obtained by all study participants.

Appendix A

Construction of the indifference curves
To estimate indifference curves, we assume a constant elasticity of substitution (CES) household production function, taking the following specification

\[ Q = \frac{A}{\left(1 - \sigma\right)} \left(\sum_{i=1}^{n} a_i x_i^{\sigma} \right)^{1/(1-\sigma)} \]

where

- \(Q\) is the total quantity produced,
- \(A\) is the total market supply,
- \(\sigma\) is the elasticity of substitution,
- \(a_i\) are the coefficients for each good,
- \(x_i\) are the quantities of each good.

This specification allows for a flexible functional form that can accommodate both convex and concave indifference curves, depending on the value of \(\sigma\). For small values of \(\sigma\), the curves become more convex, reflecting diminishing marginal rates of substitution. Conversely, for large values of \(\sigma\), the curves become more linear, indicating constant marginal rates of substitution. By estimating the parameters of this function using econometric methods, researchers can derive the indifference curves that reflect the preferences and constraints of households or individuals, providing valuable insights into their decision-making processes.
where income from household production, \( U \), sub-
sumes the technology parameter:

\[
U = (\alpha C^\gamma + (1 - \alpha) G^\rho)^{\frac{1}{\gamma}}.
\]  

(1)

\( C \) represents number of owned cattle, \( G \) represents number of owned shoats, \( \alpha \) is the CES share parameter, and \( \rho \) is the CES substitution parameter. Along a household production level set, we derive a first order condition:

\[
\frac{dG}{dC} = \frac{w_C}{w_G} = \frac{\alpha C^{\rho-1}}{(1 - \alpha) G^{\rho-1}}.
\]  

(2)

Survey data on \( C \) and \( G \) enable estimation of \( \alpha \), \( \rho \), and the livestock price ratio \( w_C/w_G \), the latter of which is equal to the marginal rate of technical substitution (MRTS). Assuming pastoralists balance shoats as a function of permit price up to a second-order Taylor approximation:

\[
\frac{w_C}{w_G} = \frac{dG}{dC}.
\]  

(3)

To recover the right-hand side of equation (4), we calculate the change in the herd sizes of cattle and shoats as a function of permit price up to a second-order Taylor approximation:

\[
p = \mu_0 + \mu_1 C + \mu_2 G^2 + \epsilon
\]

(5)

\[
p = \tau_0 + \tau_1 G + \tau_2 G^2 + \epsilon
\]

(6)

where \( p \) is the monthly price for grazing permits, \( C \) is total cattle herd size, and \( G \) is total shoat herd size. These curves can be used to compute the right-hand side of equation (4):

\[
\frac{-dp}{dC} = \frac{-dG}{dC}.
\]

(7)

Equation (7) expresses the MRTS for the subset of pastoralists who have a defined slope for cattle and shoats as a function of grazing permit price, which is about a quarter of the sample. \(^{21}\)

### Rotating the budget constraints

To simulate the budget constraint rotation (a shift to a counterfactual of no permit market), we begin by rearranging equation (2) for \( C \):

\[
C = \left( \frac{\text{MRTS} \times (1 - \alpha) G^{\rho-1}}{1 - \alpha} \right)^{\frac{1}{\rho-1}}.
\]

(8)

Equation (8) expresses the optimal number of owned cattle as a function of the number of owned shoats and individual preferences. The current budget line—with permits in place—takes the following form:

\[
G = G_1 - \text{MRTS} \times C
\]

(9)

where \( G_1 \) is the shoat-price intercept of the budget constraint and MRTS equals the magnitude of the slope. In figure 1, equation (9) is the straight dashed line. This line is rotated in by subtracting the consumer surplus (put in terms of grazing permits) from the original cattle-intercept. After the budget constraint is rotated inwards, the new slope is denoted as \( b \): the slope of the straight solid line in figure 1. To find the shoat-cattle bundle chosen without permits, we substitute \( C \) from equation (8) into equation (9), and change the slope term, MRTS, to the new slope \( b \). Solving jointly for the new optimal number of shoats, \( G^* \), and cattle, \( C^* \), yields:

\[
G^* = \frac{G_1}{1 + b \left( \frac{\alpha - 1}{\alpha} \right)^{\frac{1}{\rho-1}}}
\]

(10)

\[
C^* = \frac{G_1 - G^*}{b}.
\]

(11)

#### Empirically estimating the indifference curves

To estimate the CES preference parameters, we rearrange the first-order condition to a form that can be estimated by linear regression, noting that the price ratio \( w_C/w_G \) is equal to MRTS at each price level. Taking the natural log of the first-order condition in equation (2) and simplifying yields:

\[
\log \left( \frac{w_C}{w_G} \right)_{ij} = \log \left( \frac{\alpha}{1 - \alpha} \right) + (\rho - 1) \log \left( \frac{C}{G} \right)_{ij} + \gamma_{ij} + \kappa_j \log \left( \frac{C}{G} \right)_{ij} + \epsilon_{ij}.
\]

(12)

where \( i \) indexes the five given permit prices and \( j \) indexes individuals. The index \( j \) accounts for all non-price varying attributes of individuals in the survey. Equation (12) is suitable for estimating mean values of \( \alpha \) and \( \rho \) for the sample. In order to get parameters for each individual, we add in fixed effects \( \gamma_j \) and \( \kappa_j \):

\[
\log \left( \frac{w_C}{w_G} \right)_{ij} = \log \left( \frac{\alpha}{1 - \alpha} \right) + (\rho - 1) \log \left( \frac{C}{G} \right)_{ij} + \gamma_{ij} + \kappa_j \log \left( \frac{C}{G} \right)_{ij} + \epsilon_{ij}.
\]

(13)

Equation (13) allows computation of a CES indifference curve for each respondent with a computable MRTS. The estimated slope identifies the substitution parameter:

\(^{21}\) An MRTS likely exists for the others, but it is not recoverable by looking at contracting for grazing permits.
\[ \hat{\rho}_j = B + \kappa_j + 1. \quad (14) \]

\( B \) is the calculated global parameter on log \((C_G)\) in equation (13). To solve for the individual share parameter \( \hat{\alpha}_j \), where \( \bar{\alpha} \) is the \( \alpha \) inside the first log term on the right-hand side of equation (13):

\[ \hat{\alpha}_j = \frac{\bar{\alpha} e^{\gamma_j}}{1 + \bar{\alpha} (e^{\gamma_j} - 1)}. \quad (15) \]

We use these \( \hat{\alpha}_j \)'s and \( \hat{\rho}_j \)'s to compute individual CES indifference curves for every respondent. We assign the median \( \hat{\rho}_j \) and median \( \hat{\alpha}_j \) to the three-quarters of respondents whose MRTS cannot be computed from the data.

**Appendix B**

**First, I want to get to know you**

1. What is your gender? ___ Male ___ Female
2. How old are you? _____ years
3. How many people are in your family?
4. How many years of education have you completed?
5. Do you have children? How many? ____ sons ____ daughters
6. How many livestock do you own? ____ steers ____ heifers ____ sheep/goats
7. How many herders do you have? ____ for cattle ____ for sheep/goats
8. How many livestock did you own two years ago? ____ steers ____ heifers ____ sheep/goats
9. Is anybody in your family employed? Doing what?
10. How many children do you have in school? ____ sons ____ daughters
11. How many children do you have in college or university? ____ sons ____ daughters
12. Does your house have electricity? ___ Yes ___ No
12.1. If yes:
12.1.1. Do you own a television? ___ Yes ___ No
12.1.2. Do you own an electric stove? ___ Yes ___ No
13. How many rooms does your house have?
14. Do you own a motorcycle? ___ Yes ___ No
15. Do you own a car? ___ Yes ___ No
16. How many mobile phones are in your family?
17. How many camels do you own?
18. How many cattle do you currently have on a nearby ranch?
19. How many of your cattle do nearby ranches purchase every year?

**Next, I want to gauge your preferences through a couple short activities**

(Note: the order of the options in Q20 was randomized.)

20. If someone approached you and wanted to take a 450 kg heifer from you, how much of the following items would they have to give you in return? Remember that if another community offers a lower price, then the trader will likely trade with them and not you. It also okay to say you would not trade a heifer for any amount of the good being offered.

_____ steers ___ I would never give up a heifer for any amount of steers
_____ sheep/goats ___ I would never give up a heifer for any amount of sheep/goats
_____ months of the right to graze one cattle on a nearby ranch ___ I would never give up a heifer for any amount of grazing rights
_____ ksh of SIM card airtime ___ I would never give up a heifer for any amount of SIM card airtime
_____ smartphones ___ I would never give up a heifer for any amount of smartphones
_____ terms of school fees for son ___ I would never give up a heifer for any amount of school fees for a son
_____ terms of school fees for daughter ___ I would never give up a heifer for any amount of school fees for a daughter
_____ kg of maize ___ I would never give up a heifer for any amount of maize
_____ months of electricity for your house ___ I would never give up a heifer for any amount of electricity
_____ ksh cash ___ I would never give up a heifer for any amount of cash

21. Imagine a nearby ranch will sell rights to graze on its land to only a few households. Everyone will make an offer, put it in an envelope, and seal it. Nobody will know each other’s offers, but the rancher will see them all and choose the households who offered the most money. How much money would you offer the ranch per head of cattle, per month, to graze on their land under the following deals?

The rancher provides herders and metal bomas, sprays for ticks twice a month
_____ ksh/head/month

The rancher provides only metal bomas and dictates where you are allowed to take your cattle
_____ ksh/head/month

The rancher provides nothing, but you may manage your cattle however you wish on the land
_____ ksh/head/month

22. Please tell us what would most likely happen on the group ranch if you won the right to graze two animals on a nearby ranch during the dry season.

(a) I would get more cattle to graze on the group ranch.
(b) Other community members’ livestock would eat the grass on the group ranch that my two animals did not eat.

(c) There would be more grass for my animals on the group ranch later in the season.

23. How many animals would you own if a nearby ranch let you graze there for:

0 ksh/head/month ______ total cattle ______ cattle on the ranch ______ sheep/goats
250 ksh/head/month ______ total cattle ______ cattle on the ranch ______ sheep/goats
500 ksh/head/month ______ total cattle ______ cattle on the ranch ______ sheep/goats
750 ksh/head/month ______ total cattle ______ cattle on the ranch ______ sheep/goats
1000 ksh/head/month ______ total cattle ______ cattle on the ranch ______ sheep/goats

24. Would you be willing to sell your cattle to a nearby ranch?  ___ Yes  ___ No

25. What is the lowest price you would be willing to accept for a nearby ranch to buy your cattle? Keep in mind if you charge too high of a price, the rancher will choose to buy cattle from someone else. You can refuse to sell at all prices, but then you will be responsible for taking your cattle to market.

_____ ksh/kilo

26. What herd size would you maintain if a nearby ranch was willing to buy your cattle at:

50 ksh/kilo ______ steers ______ heifers ______ sheep/goats
100 ksh/kilo ______ steers ______ heifers ______ sheep/goats
150 ksh/kilo ______ steers ______ heifers ______ sheep/goats
200 ksh/kilo ______ steers ______ heifers ______ sheep/goats
250 ksh/kilo ______ steers ______ heifers ______ sheep/goats

Now, I want to learn how you graze your animals

28. Please indicate which locations you use in a wet year. Please indicate to us the order you move through them.

29. Please indicate which locations you use in a dry year. Please indicate to us the order you move through them.

30. Do you expect competition with other pastoralists if you do not move to these lands?

31. For areas that you use other than the group ranch, do you have a formal right to use the area?

(a) Yes, always
(b) Some, but not all
(c) None

31.1. If (a) or (b):

How much do you compensate the owner?

How many animals do you put on those lands?

31.2. If (c):

How many animals did you take when you walked on?

Lastly, I want to play a game with you

I am going to roll a die. Before I roll it, you will choose one of six ‘gambles’, with payoffs described below. After I roll, I will give you a cash amount corresponding to the gamble you selected. Good luck!

(Note: For half the respondents, this game appeared after Q16 above. The respondents receiving each question order were chosen randomly.)

Gamble 1
White: 60 ksh
Blue: 60 ksh
Gamble 2
White: 50 ksh
Blue: 75 ksh
Gamble 3
White: 40 ksh
Blue: 90 ksh
Gamble 4
White: 30 ksh
Blue: 105 ksh
Gamble 5
White: 20 ksh
Blue: 120 ksh
Gamble 6
White: 0 ksh
Blue: 135 ksh

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References

Barrios A, de Valck K, Shultz C J, Sibai O, Husermann K C, Maxwell-Smith M and Luedicke M K 2016 Marketing as a means to transformative social conflict resolution: lessons from transitioning war economies and the Colombian coffee marketing system J. Public Policy Market. 35 185–97

Bento A, Ho B and Ramirez-Basora M 2015 Optimal monitoring and offset prices in voluntary emissions markets Resour. Energy Econ. 41 202–23

Boles O J C, Shoemaker A, Courtney Mustaphi C J, Petek N, Ekblom A and Lane P J 2019 Historical ecologies of pastoralist overgrazing in Kenya: long-term perspectives on cause and effect Hum. Ecol. 47 419–34

Bond J 2014 A holistic approach to natural resource conflict: the case of Laikipia County, Kenya J. Rural Stud. 34 117–27

Burke J 2017 Inequality, drought and the deadly fight for precious grazing land in Kenya The Guardian (3 May) (available at: www.theguardian.com/world/2017/may/03/inequality-drought-and-the-deadly-fight-for-precious-grazing-land-in-kenya (Accessed 4 March 2020))

Butynski T M and Jong Y A 2014 Primate Conservation in the Rangeland Agroecosystem of Laikipia County, Central Kenya Primate Conservation 28 117–28

Coase R H 1960 The problem of social cost J. Law Econ. 3 1–44
Crawford C L, Volencic Z M, Sisanya M, Kibet R and Rubenstein D I 2019 Behavioral and ecological implications of bunched, rotational cattle grazing in East African savanna ecosystem Rangel. Ecol. Manage. 72 204–9
Dave C, Eckel C C, Johnson C A and Rojas C 2010 Eliciting risk preferences: when is simple better? J. Risk Uncertain. 41 219–43
Deininger K 1999 Making negotiated land reform work: initial experience from Colombia, Brazil and South Africa World Dev. 27 651–72
Desta S and Coppelock D L 2004 Pastoralism under pressure: tracking system change in Southern Ethiopia Hum. Ecol. 32 465–86
Dorius N 1993 Land use negotiation reducing conflict and creating wanted land uses J. Am. Plan. Assoc. 59 101–6
Eckel C C and Grossman P J 2002 Sex differences and statistical stereotyping in attitudes toward financial risk Evol. Hum. Behav. 23 281–95
Ellis J F and Swift D M 1988 Stability of African pastoral ecosystems: alternate paradigms and implications for development Rangel. Ecol. Manage. 41 450–9
Fox G R 2018 Maasai group ranches, minority land owners, and the political landscape of Laikipia County, Kenya J. East. Afr. Stud. 12 473–93
Fratkin E 2001 East African pastoralism in transition: Maasai, Boran, and Rendille cases Afr. Stud. Rev. 44 1–25
Georgiadis N, Ojwang G, Olwero N and Aike G 2011 Reassessing aerial sample surveys for wildlife monitoring, conservation, and management Smithson. Contrib. Zool. 632 31–42
Hart S 2008 Meat goat nutrition Proc. 23rd Ann. Goat Field Day (Langston University) pp 58–83 (available at: www.luresext.edu/sites/default/files/2008%20Field%20Day.pdf) (Accessed 28 April 2020)
Hauck S and Rubenstein D I 2017 Pastoralist societies in flux: a conceptual framework analysis of herding and land use among the Mukugodo Maasai of Kenya Pastoralism 7 18
Hah J M, Ngairu J K W and Ogindo H O 2011 Living with drought: the case of the Maasai pastoralists of northern Kenya Educational Research 2 779–89 (www.researchgate.net/publication/228341183_Living_with_drought_the_case_of_the_Maasai_pastoralists_of_northern_Kenya)
Johnston R J et al 2017 Contemporary guidance for stated preference studies J. Assoc. Environ. Resour. Econ. 4 319–405
Kinzig A P, Perring S C, Chapin F S, Polasky S, Smith V K, Tilman D and Turner B L 2011 Paying for ecosystem services—promise and peril Science 334 603–4
Leithead A 2017 Herders overrun Kenya tourist ranch BBC News (4 February) (available at: www.bbc.com/news/world-africa-38866389) (Accessed 4 March 2020)
Lewis A 2015 Amboseli Landscapes: Maasai Pastoralism, Wildlife Conservation, and Natural Resource Management in Kenya, 1944–present Doctoral Dissertation Michigan State University (https://doi.org/10.25353/M59N3J)
McCabe J T 1997 Risk and uncertainty among the maasai of the ngorongoro conservation area in tanzania: a case study in economic change Nomadic Peoples 1 54–65 (www.jstor.org/stable/43123510)
Millard-Ball A 2013 The trouble with voluntary emissions trading: uncertainty and adverse selection in sectoral crediting programs J. Environ. Econ. Manage. 65 40–55
Montero J 1999 Voluntary compliance with market-based environmental policy: evidence from the U. S. acid rain program J. Polit. Econ. 107 998–1033
Odadi W O, Fargione J and Rubenstein D I 2017 Vegetation, wildlife, and livestock responses to planned grazing management in an African pastoral landscape Land Degrad. Dev. 28 2030–8
Odadi W O, Jain M, Wieren S E V, Prins H H T and Rubenstein D I 2011 Facilitation between bovids and equids on an African savanna Evol. Ecol. Res. 13 237–52 (www.researchgate.net/publication/239848265_Facilitation_between_Bovids_and_Equids_in_an_African_Savanna)
Ogutu J O, Piepho H-P, Said M Y, Ojwang G O, Njino L W, Kifugo S C and Wargute P W 2016 Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: what are the causes? PLoS One 11 e0163249
Osterle M 2008 From Cattle to Goats: The Transformation of East Pokot Pastoralism in Kenya Nomadic Peoples 12 81–91
Ostrom E 1990 Governing the Commons: The Evolution of Institutions for Collective Action 1 (Cambridge: Cambridge University Press)
Peacock C and Sherman D M 2010 Sustainable goat production—Soome global perspectives Small Rumin. Res. 89 70–80
Regional Pastoral Livelihoods Resilience Project 2020 Community grazing agreements for resource sharing and peace building (available at: https://icpald.org/wp-content/uploads/2020/01/07-RPLRP_Laikipia_GF_Grazing-Agreements-1.pdf) (Accessed 14 November 2021)
Rosa García R, Celaya R, García U and Osoro K 2012 Goat grazing, its interactions with other herbivores and biodiversity conservation issues Small Rumin. Res. 107 49–64
Salzman J, Bennett G, Carroll N, Goldstein A and Jenkins M 2018 The global status and trends of payments for ecosystem services Nat. Sustain. 1 136–44
Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M and de Haan C 2006 Livestock’s Long Shadow: Environmental Issues and Options Food and Agriculture Organization of the United Nations (https://www.fao.org/3/a0701e/a0701e00.htm)
Sundaresan S R and Riggins C 2010 Lessons learned from biodiversity conservation in the private lands of Laikipia, Kenya Great Plains Research 20 17–27 (http://digitalcommons.unl.edu/greatplainsresearch/1081)
Witt A BR, Nunda W, Beale T and Kitisico D J 2020 A preliminary assessment of the presence and distribution of invasive and potentially invasive alien plant species in Laikipia County, Kenya, a biodiversity hotspot KOEDOE - African Protected Area Conservation and Science 62
Yung L and Belsky J M 2007 Private property rights and what are the causes? J. Assoc. Environ. Resour. Econ. 4 408–30 (Accessed 28 April 2020)
Ostrom E 1990 Governing the Commons: The Evolution of Institutions for Collective Action 1 (Cambridge: Cambridge University Press)
Peacock C and Sherman D M 2010 Sustainable goat production—Soome global perspectives Small Rumin. Res. 89 70–80
Regional Pastoral Livelihoods Resilience Project 2020 Community grazing agreements for resource sharing and peace building (available at: https://icpald.org/wp-content/uploads/2020/01/07-RPLRP_Laikipia_GF_Grazing-Agreements-1.pdf) (Accessed 14 November 2021)
Rosa García R, Celaya R, García U and Osoro K 2012 Goat grazing, its interactions with other herbivores and biodiversity conservation issues Small Rumin. Res. 107 49–64
Salzman J, Bennett G, Carroll N, Goldstein A and Jenkins M 2018 The global status and trends of payments for ecosystem services Nat. Sustain. 1 136–44
Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M and de Haan C 2006 Livestock’s Long Shadow: Environmental Issues and Options Food and Agriculture Organization of the United Nations (https://www.fao.org/3/a0701e/a0701e00.htm)
Sundaresan S R and Riggins C 2010 Lessons learned from biodiversity conservation in the private lands of Laikipia, Kenya Great Plains Research 20 17–27 (http://digitalcommons.unl.edu/greatplainsresearch/1081)
Witt A BR, Nunda W, Beale T and Kitisico D J 2020 A preliminary assessment of the presence and distribution of invasive and potentially invasive alien plant species in Laikipia County, Kenya, a biodiversity hotspot KOEDOE - African Protected Area Conservation and Science 62
Yung L and Belsky J M 2007 Private property rights and community goods: negotiating landowner cooperation amid changing ownership on the Rocky Mountain Front Soc. Nat. Resour. 20 689–703