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Economic valuation of grazing management practices: discrete choice modeling in pastoral systems of Kenya

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This study estimates the economic contribution of grazing management practices in pastoral systems by specifically undertaking an economic analysis of pastoralists' preferences for grazing management practices and the economic value pastoralists place on them. The study applied the discrete choice experiment technique using a D-optimal design, a multi-attribute preference elicitation method to evaluate the economic value of grazing management options practiced in pastoral areas of Kenya. The results show that pastoral communities derive positive utility in connected systems that enable reciprocal access to resources in both wet and dry seasons. Pastoralism adapts to spatial-temporal variability of pasture and water through herd mobility; hence the positive utility derived from practices that contribute to the availability of adequate water and pasture across the seasons. These findings provide empirical evidence on the social and economic net benefits of rangeland management practices that should be enhanced to promote sustainable management of rangeland resources.

Keywords: discrete choice experiment; economic values; grazing management; pastoralism; welfare values

1. Introduction

Rangelands, primarily comprised of savannas and shrub-lands, are found mainly in arid and semi-arid zones, which cover about 41% of the global landmass (Kuntu-Blankson *et al.* 2018). In Africa, rangelands make up to 43% of the total land surface area. In Kenya, rangelands constitute approximately 80% of the land mass and support over 70% of the livestock population.

African rangelands are characterized by low, spatially and temporally variable rainfall in addition to hot temperatures, leading to high levels of evapotranspiration. Given the scanty vegetation cover found in most rangelands in Africa, they also experience high run off, leading to floods (Mwangi and Dohrn 2006), particularly during heavy storms, which makes them more disposed to degradation (Reid, Galvin, and Kruska 2008).

Regardless of the climatic limitations, rangelands are socio-economically and ecologically important. They offer a variety of ecosystem goods and services, with direct

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and indirect economic and social benefits to their inhabitants. Specifically, because these areas support the livelihoods of over 40% of the world's population (De Jode 2009), there is growing recognition of their importance in meeting the basic needs of their inhabitants, as well as global food security (Mortimore *et al.* 2009). In terms of ecological significance, rangelands provide habitats for wildlife and, as observed by Lund (2007), they also act as water catchments for various river systems. Besides, rangelands are also important areas for storage of about 30% of world soil carbon (FAO 2009). This implies that sustained higher levels of investment in the management of semi-arid areas can immeasurably support enhanced productivity and better incomes.

A fundamental transformation in management practices, as well as better dissemination of knowledge and improved land-use technologies and access to urban markets have the potential to sustainably enhance production and livelihoods in these areas. Investments in rangelands have largely focused on enhancing livestock production by increasing forage production. This is because livestock production in arid and semi-arid areas is an important source of household food and income and provides an important avenue for employment, especially when proper grazing and rangeland management practices that enhance productivity are put in place (Thornton 2010).

Various management practices have been put in place to promote sustainable management of rangeland resources globally in order to enhance livestock production and protect rangelands from degradation. Some of these practices have not been able to produce the desired levels of productivity and have thus failed to improve the welfare of the pastoral communities or prevent rangelands from deteriorating (MacLeod and Brown 2014; Torell *et al.* 2013).

An important contributing factor to the failures of the range management practices is the paucity of comprehensive information on the socio-economic value of their impacts (Costanza *et al.* 2016). The management of rangelands requires many decisions that would be facilitated by an understanding of the pastoralists' preferences for the grazing management practices to be included in rangeland management plans. Failure to include social and economic non-market values in decision-making processes may lead to undervaluing the net benefits of rangeland practices, which affects allocation of investments in conservation and ultimately leads to their degradation (Kelemen *et al.* 2014).

This study employed the discrete choice experiment (DCE) method to investigate pastoralists' preferences for various grazing management options and their economic value. A DCE is a stated preference approach that can be used to value non-marketed goods and services (Garrod *et al.* 2014; Scarpa *et al.* 2003). Modeling pastoralists' choices allowed evaluation of how they would trade-off different levels of grazing management attributes, as described in Lancaster's theory of consumer choice (Lancaster 1966), which suggests that consumers derive their satisfaction from the attributes of a good, and not just from the good *per se*.

2. Methods and study area

The study was conducted in the rangeland areas of Tana River County located in the north eastern side of Kenya, as shown in Figure 1. Tana River County has three sub counties – Bura, Galole and Garsen – inhabited primarily by the Orma, Wardey and Pokomo ethnic communities. The Ormas and Wardeys are pastoralists and move seasonally in search of pasture and water, while the Pokomo are agro-pastoralists who

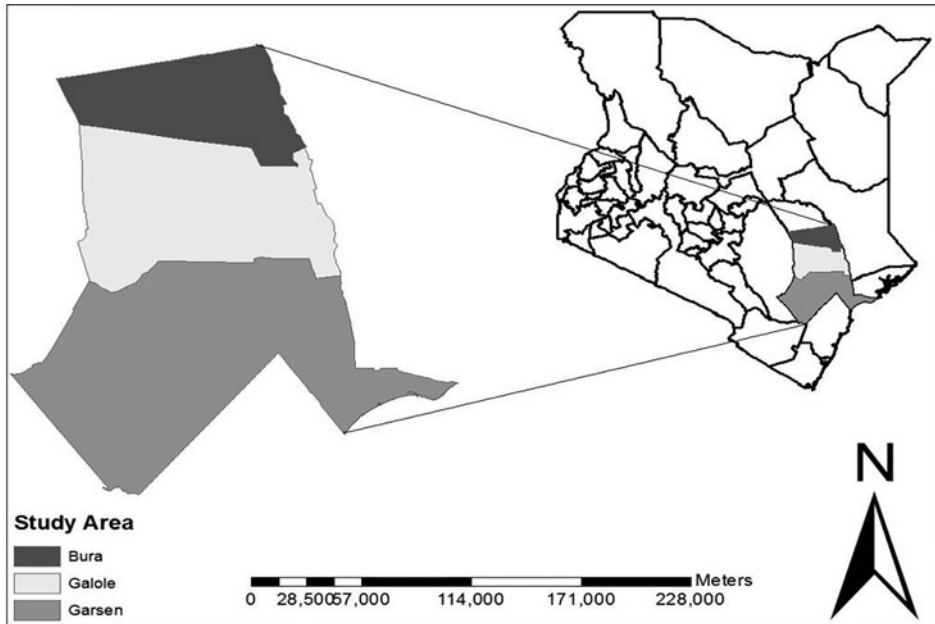


Figure 1. The study area.

have settled along river banks where they undertake small-scale subsistence farming (Kipchirchir 2014).

Tana River County has arid and semi-arid climatic conditions characterized by a hot and dry climate. Average annual temperatures are about 30 °C, with the highest being 41 °C around January–March and the lowest being 20.6 °C during June–July (Kipchirchir 2014). Rainfall is low, bimodal, erratic and localized in nature. The total annual rainfall ranges between 220 and 500 mm with long rains occurring in April and May, while short rains fall in October and November, with November being the wettest month (Kipchirchir 2014).

2.1. Study design

This study used a DCE design to determine the economic value of grazing management practices. The DCE approach has been widely used to determine the economic values of the effects of various environmental interventions (Hanley, Mourato, and Wright 2001; Hanley, Wright, and Alvarez-Farizo 2006; Scarpa *et al.*, 2003). DECs are based on stated preferences, since they bring about information regarding individuals' preferences in relation to environmental goods and services through the construction of a hypothetical, but realistic, market, rather than on preferences revealed by the actual behavior of individuals (Garrod *et al.* 2014; Ruto and Garrod 2009). The DCE technique is centered on random utility theory and the characteristics theory of value (Lancaster 1966), which postulates that utility derived from the consumption of goods is determined by the attributes of the goods and not the goods themselves. The decision to use a DCE approach for this study was driven by the desire to estimate values for different component parts of grazing management practices. The component parts constitute the attributes in the DCE design. In order to construct the design, grazing

management practices were decomposed according to their attributes (or characteristics), and the combination of various levels of this set of attributes resulted in a scenario of change in environmental quality.

2.1.1. *Grazing management practices and their attributes*

As required in the construction of the DCE design (Scarpa *et al.* 2003), the most important component attributes of the grazing options/scenarios used in the design of this study were identified by the local community members, including community leaders, government officials of Tana River County and the representatives of water resource user associations through focus group discussions (FGD). A total of six FGD, comprising men, women and youths were conducted to investigate pastoralists' attitudes towards grazing management practices and to obtain information on the features of the grazing scenarios that are important to them. The choice of attributes and levels was also based on a combination of evidence from the literature and information from FGD with pastoralists in all the study sites. The grazing management practices and their attributes included:

Regulation of grazing by designating wet and dry season grazing areas: Grazing ban in areas near the permanent water points at the peak of the wet season was meant to preserve them for dry season grazing. During the wet season, when forage is plentiful, grazing animals are to be moved far away from the permanent water points and only come back during the dry season. This would take either *two months* (shortest duration of grazing animals away from the dry season grazing areas) or *six months* (the longest duration of grazing away from the permanent water points used as the dry season grazing areas).

High intensity, short duration grazing alternated with long rest periods: Maximizing stocking density to ensure forage threshold below which grazing is not possible, to avoid overgrazing and land degradation. In this regard, pastoralists are to ensure that grazing livestock assert maximum impact on the pasture and soil in a particular area for the shortest time possible, and allow ample time for the grazed pasture to regenerate before grazing again. Keeping animals in one place for a shortest duration of less than two days would be considered a *high threshold*; five days would be a *medium threshold*, while keeping animals for more than a week would be considered to be a *low threshold*.

Construction of additional water pans: Construction of additional water pans in the wet season grazing areas is necessary to ensure that animals do not return to the permanent water sources situated in the dry season grazing areas before the right time. In this regard, there are only two options; whether to construct more water pans in the wet season grazing areas or not.

Increased biomass yield and greater water availability are the outputs for improved grazing management. Construction of additional water pans, preventing degradation and overgrazing and preserving dry season grazing areas would have a positive effect on biomass yield and water availability in the grazing areas. Water pans capture and store more rain water that often runs off. This would benefit the community and provide pasture and water across the seasons.

According to Scarpa *et al.* (2003), it is possible to determine the welfare estimates for a combination of attribute changes by including price or cost as one of the attributes. This enables estimation of willingness-to-pay for changes in attribute levels (Ruto

Table 1. Grazing management attributes used in DCE.

Management attribute	Description	Levels
Construction of additional water pans	Construction of additional water pans in the wet season	No Yes
Forage threshold below which grazing is not allowed	The minimum amount of forage below which grazing is restricted to allow grazed pasture to regenerate after use.	High threshold Medium threshold Low threshold
Grazing ban near water points in wet season	Grazing ban near permanent water points during the peak of the wet season to reserve pasture for dry season grazing	Two months ban Six months ban
Increased forage production	Amount of forage produced	High forage production Medium forage production Low forage production
Increased water availability	Water availability in the water-pans and more infiltration into the soil	More water Less water
Annual grazing fee	Annual fee paid by households for membership in the use of grazing areas	KSh. 600 KSh. 720 KSh. 900

and Garrod 2009). Therefore, in addition to the selected attributes, a monetary attribute (price level) was included in this design to enable the calculation of welfare measures. Currently, in each community in the study site where there is a water-pan, each household contributes 50 Kenyan shillings, which translates to 600 shillings (six US dollars) per annum. The money is meant to pay the personnel guarding the water pan and also to ensure that it is well maintained. During the FGDs, the members agreed that given the addition of forage yield and more water in the water pans to accommodate all the households in the community they would be more willing to pay an addition of either 10 or 25 Kenyan shillings per month. This, therefore, informed the price levels of 720 and 900 Kenyan shillings per annum, respectively, in this design. The common attributes for the grazing management practices identified in the FGD held in study areas that were used in this design are shown in Table 1.

In order to reduce the D-error and increase sampling efficiency, a two-stage design procedure was used to maximize D-optimality (Bliemer and Rose 2010). The first stage involved a preliminary survey of 60 respondents in Galole, Bura and Garsen sub-counties of Tana River County to obtain coefficients that were then used to generate an efficient design in the second stage. The efficient design generated in the second stage had a relatively good level of D-optimality (D-efficiency measure of 82%) and a good utility balance (B-estimate of 81%), which according to Otieno, Ruto, and Hubbard (2011) indicates that there was an insignificant likelihood of dominance by any alternative in the choice situations. The final design had 24 paired choice profiles that were randomly blocked into six sets of four choice tasks.

Each respondent in the study area was randomly assigned to one of the six sets and asked to choose the most preferred option in each choice task. Each choice task

Table 2. A choice set used in the DCE design.

Grazing management attributes	Alternative A	Alternative B	Alternative C
Construction of water pans	Yes	No	No addition
Biomass threshold to stop grazing	High	Medium	No threshold
Grazing ban in the wet season	Six months	Two months	No grazing ban
Forage yield	Lower yield	Medium yield	No extra forage produced
Water availability	Less water storage capacity	More water storage capacity	No influence
Annual membership fee (Ksh)	600	900	No membership fee
Which alternative do you prefer?			

Source: Authors compilation based on FGDs.

had two alternatives (1 and 2) and the baseline or *status quo* (3), as shown in Table 2. A baseline/*status quo* scenario which showed the conditions as they were on the ground without any intervention was incorporated into the choice set as an alternative. This allowed those respondents who were satisfied with the *status quo* to select neither of the proposed alternatives without being forced to change which, according to Hanley, Mourato, and Wright (2001) and Ruto and Garrod (2009), helps the results obtained in the analysis to be more consistent with demand theory. It is only the attributes presented in the choice set that were considered in the choices by the respondents during the survey. They were asked to consider each choice set independently of the other. Experimental design software called NGENE was used to generate the design (Choice Metrics 2009).

Adequate information was provided to enable respondents to understand the DCE exercise and be able to make independent and reliable choices in each situation, based on their preferences. Each respondent was presented with a series of choice sets, randomly chosen from one of the six blocks of choice sets from the DCE design, and asked to choose the most preferred option in each case.

2.2. Data collection

A multistage sampling procedure was used to determine the sampling frame in this study. Three sub-counties namely: Bura, Galole and Garsen inhabited by the agro-pastoralists and the nomadic pastoralists were purposively selected in the first stage of sampling. The second stage involved a systematic random sampling to select five locations from each sub-county, giving a total of 15 locations from which sampling was undertaken. This procedure was repeated in the third stage by narrowing down to two smaller administrative units (sub-locations) within each location using the systematic random sampling technique, giving a total of 30 sub-locations.

A formula by Orme (1998) shown in Equation (1) was used to compute the appropriate sample size for the study, taking into consideration the projected number of households in the selected sub-locations

$$N = 500 \times \left(\frac{L}{J \times T} \right) \quad (1)$$

where N is the sample size, L is the largest number of levels for any of the attributes, J is the number of choice alternatives and T is the number of choice situations in the design. In this study, where $L=3$, $J=3$ and $T=5$, the sample size was 100 respondents per sub-county. Given the three sub-counties, the total sample size was 300 respondents (100 * 3 sites). Data were collected through household surveys involving face-to-face interviews.

2.3. Data analysis

Each respondent was presented with a series of $M=4$ choices. In each choice set, a respondent faced a choice between $J=2$ alternatives of grazing management plus a *status quo*. In each scenario (choice set), respondents were asked to choose between two grazing management alternatives allowing for a *status quo*. The *status quo* represented the respondent's current feasible choice set. This is important in interpreting the results in standard welfare economic terms (Hanley, Mourato, and Wright 2001). Therefore, the attributes of alternative i in choice situation t faced by individual n are collectively labeled as a vector X_{int} . Revelt and Train (1998) give the specification of the utility derived by person n from alternative j as follows:

$$u_{nj} = \beta_n X_{nj} + \varepsilon_{nj} \quad (2)$$

where X_{nj} are the observed variables that relate to the alternative and the decision maker, β_n a vector of coefficients of these variables for person n representing that individual's tastes and ε_{nj} is a random term that is *iid* extreme value (for simplicity, the subscript t for choice situation is suppressed). The coefficients vary over decision makers in the population with density $f(\beta_n/\theta)$. This density is a function of parameters θ that represent the mean and covariance of the β 's in the population.

The value of β_n and ε_{nj} is only known to the decision maker for all j alternatives and chooses alternative i if and only if $U_{ni} > U_{nj} \neq i$. The probability that individual n chooses alternative i conditional on β_n is given by the standard multinomial logit model (MNL) as follows:

$$L_{ni}(\beta_n) = \frac{e^{\beta_n X_{ni}}}{\sum_{j \neq n} e^{\beta_n X_{nj}}} \quad (3)$$

Let $i(n)$ denote the alternative chosen by individual n in choice situation t . The probability of individual n 's observed sequence of choices (conditional on β_n) is the product of the MNL with the assumption that the individual tastes, β_n do not vary over choice situations in repeated choice tasks (although are assumed heterogeneous over individuals):

$$G_n(\beta_n) = \prod L_{ni}(\beta_n) \quad (4)$$

Thus, the choice probability follows the expression:

$$P_n(\theta) = \int G_n(\beta_n) f(\beta_n/\theta) d\beta \quad (5)$$

The expression in Equation (5) has two sets of parameters. The β_n is a vector of parameters that are specific to individual n (representing individual tastes, which vary between respondents) and θ are parameters that describe the distribution of the individual specific estimates.

The main objective of random parameter logit (RPL) is to specify the function $f(\beta_n/\theta)$ and estimate the parameter θ . The estimation of the parameter θ is done through simulation of the choice probability. This is attributed to the fact that the integral equation cannot be computed analytically due to its mathematical closed form (Train 2003).

The log-likelihood function is specified as:

$$LL(\theta) = \sum_n L_n P_n(\theta) \quad (6)$$

The $P_n(\theta)$ is approximated by a summation over randomly chosen values of β_n . For a selected value of parameter θ , a value of β_n is drawn from its distribution and $G_n(\beta_n)$ representing the product of the standard MNL is computed. Repeated calculations are done for several draws and the average of $G_n(\beta_n)$ is considered as the approximate choice probability.

The average is the simulated probability given by:

$$SP_{ni}(\theta) = \frac{1}{R} \sum_{r=1}^R G_n(\beta_n^r) \quad (7)$$

where R is the number of draws and $SP_{ni}(\theta)$ is unbiased estimator of $P_{ni}(\theta)$ by construction. The $P_{ni}(\theta)$ is twice differentiable in the parameter θ and variable x , which facilitates the numerical search for the maximum likelihood function and the calculation of elasticities. Then, the simulated probabilities are inserted into the log-likelihood function to give a simulated log-likelihood (SLL) function given as:

$$SLL(\theta) = \sum_n \ln(SP_n(\theta)) \quad (8)$$

The estimated parameters are those that maximize $SLL(h)$. Trade-offs between grazing management attributes and money, that is, the marginal willingness to pay (WTP), is computed as follows (Hanemann 1984):

$$WTP = -1 \times \left(\frac{\beta_k}{\beta_p} \right) \quad (9)$$

where β_k is the estimated coefficient for an attribute level in the choice set and β_p is the marginal utility of income given by the coefficient of the farmer's membership fee (cost attribute). The marginal WTP (implicit price) for a discrete change in an attribute provides a measure of the relative importance that respondents attach to attributes.

The results were derived from the analysis of the choices made by the respondents on the grazing profiles, which formed the dependent variable and the attributes described in Table 3 as the independent variables.

3. Results

3.1. Random parameter estimates for grazing management attributes

Table 4 presents the maximum likelihood estimates for the RPL model for grazing management practices. In order to estimate the WTP and avoid the possibility of

Table 3. Description of variables used in the choice analysis.

Variable	Description
WATERPAN	Construction of additional water pans in the wet season grazing areas (1 = Yes, 0 = Otherwise)
BIOTHRESH	The minimum amount of forage below which grazing is restricted to allow grazed pasture to regenerate before grazing (low, medium, high threshold)
GRAZBAN	Grazing ban near permanent water points during the peak of the wet season to reserve pasture for dry season grazing (1 = six months, 0 = two months)
BIOHIGH	High amount of forage yield (1 = Yes, 0 = Otherwise)
BIOMED	Low amount of forage yield (1 = Yes, 0 = Otherwise)
MOREWATE	More water available in the water-pans and more infiltration into the soil (1 = Yes, 0 = Otherwise)
COST	Annual fee paid for using grazing areas (KSh. 600, KSh. 720, KSh. 900)

Table 4. Random parameter estimates for the improved grazing management attributes.

Choice	Coefficient	Std. error	95% Confidence interval	
WATERPAN	4.70***	1.01	1.20	8.26
LOWBIOTH	-3.14**	1.56	-8.15	-0.07
MEDBIOTH	0.48*	3.58	-6.53	7.49
GRAZBAN	2.89**	1.37	5.62	6.13
BIOHIGH	10.57***	2.86	3.97	15.18
BIOMED	9.58*	3.07	4.3	16.37
MOREWATE	18.77***	5.79	7.04	29.75
COST	-0.00627***	0.002	-0.01	-0.002
<i>Standard deviations of parameter distributions</i>				
WATERPAN	13.98**	5.57	3.06	24.89
LOWBIOTH	5.83**	2.31	1.29	10.36
MEDBIOTH	3.89*	2.42	-0.86	8.65
GRAZBAN	8.16***	2.78	2.70	13.63
BIOHIGH	0.01***	3.01	-5.89	5.92
BIOMED	3.89*	2.43	-0.87	8.65
MOREWATE	7.02**	2.95	1.24	12.81
Log-likelihood	-160.47	-	-	-
Pseudo- R^2	0.46	-	-	-
N respondents	300	-	-	-
N choices	1,200	-	-	-

Note: *Statistical significance level: 10%.

**Statistical significance level: 5%.

***Statistical significance level: 1%.

getting extreme negative and positive trade-off values, the utility parameters for all attributes except the cost attribute, which was specified as fixed, were treated as random variables assuming a normal distribution (Revelt and Train 1998).

The results of the RPL model had a log likelihood function of -160.04 and a pseudo- R^2 of 0.46. According to Louviere *et al.* (2000), values of R^2 between 0.2 and 0.4 are considered to be indicative of extremely good model fit, equivalent to the range of 0.7–0.9 found in linear functions such as the stated choice ordinary least squares regression applications. A log likelihood ratio-test confirms that the RPL model

Table 5. Preference shares of grazing management attributes.

Attribute	Mean	Std. dev.	Negative share (%)	Positive share (%)
WATERPAN	4.70	13.98	36.84	63.16
LOWBIOTH	-3.14	5.83	70.49	29.51
MEDBIOTH	0.48	3.89	45.11	54.89
GRAZBAN	2.89	8.16	36.16	63.84
BIOHIGH	10.57	0.01	0.00	100.00
BIOMED	9.58	3.89	0.70	99.30
MOREWATE	18.77	7.02	0.37	99.63

provided a better model fit to the data compared to the conditional logit model. The results of the model in Table 4 indicate that all the mean coefficients of the attributes investigated are statistically significant ($\chi^2 = 2316$, 15 df, $p < 0.00$). The parameter estimate for annual membership fee was significant ($p < 0.01$) with a negative sign. This implies that the community members were more likely to choose the profile or participate in the management of the grazing practices that have more benefits for them at a lower cost. The negative sign allowed computation of trade-offs between each attribute and money.

The coefficients in Table 4 show that the parameter estimate for increased water levels is of greater magnitude than the rest of the parameter estimates for all the other attributes, followed closely by the high biomass yield. The model, therefore, predicts a higher probability of respondents selecting a profile with grazing management practices that will ensure more water storage capacity for the community, as well as the biomass yield that will be able to sustain their livestock. All the random parameter estimates are strongly significant, indicating that the means of these parameter estimates are statistically different from zero. Since these are random parameters, the results suggest the existence of heterogeneity in the parameter estimates that may be different from the sample population mean of the parameter estimates of these attributes. The standard deviations for the coefficients of all attributes are significant, which means there are heterogeneous preferences for these attributes. The estimated means and standard deviations of the coefficients were used to determine the proportion of the population that places a positive value on a particular attribute and the proportion that places a negative value on it (Train 2003) as shown in Table 5.

The majority of the respondents place a positive value on high biomass (100%) production and availability of more water (99.63%). However, 70.49% place a negative value on a low biomass threshold to stop grazing, which was used as a proxy for high grazing pressure that is likely to result in overgrazing. A proportion of 63.16% of the respondents would prefer the addition of waterpans, while 63.84% place a positive value on the grazing ban around the water points in the wet season to reserve them as dry season grazing areas.

3.2. Economic values of the attributes

Table 6 presents estimates of WTP for the respective attributes derived from the model. The mean welfare estimates for the random parameters were obtained by simulations, drawn from 10,000 replications in R-software, based on the RPL model results shown in Table 4.

Table 6. Economic values attached to the grazing management attributes.

Attributes	WTP (KSh)	Std. error	95% Confidence interval	
WATERPAN	432.56***	93.97	248.37	616.76
LOWBIOTH	-376.15***	110.71	-593.15	-159.15
MEDBIOTH	117.06*	357.72	-584.05	818.17
GRAZBAN	256.95**	134.53	220.68	276.68
BIOHIGH	1527.83***	263.01	1248.66	2494.98
BIOMED	1439.25***	247.65	953.87	1921.63
MOREWATER	2088.28***	369.35	1364.36	2812.21

Note: *Statistical significance level: 10%.

**Statistical significance level: 5%.

***Statistical significance level: 1%.

The estimated pastoral communities' marginal WTP for water and biomass were the highest in the ranking of the attributes. The results indicate that each household is willing to pay Ksh. 2,088 and 1,528 annually for the management of water and high biomass yield respectively. Further, results indicate that each pastoral household would be willing to accept (WTA) compensation of approximately Ksh. 376 annually for a welfare loss if a low grazing threshold is tolerated in the grazing management. Respectively, the derived WTP for the addition of water pans and dry season grazing reserves was Ksh. 432 and 256 annually.

4. Discussion

4.1. Preferences for grazing management practices

Tana River County is considered a water-scarce county in Kenya with most of the area regularly experiencing extreme water shortage during periodic dry spells. Rapid population growth and inefficient use of resources increases the deficit between available water supplies and the needs of people. The entire county is drought prone and the vulnerability of the population to drought is high, with the majority of the people in the county living in very dry areas, especially the Orma and Wardey Community. This explains why the parameter estimates for the addition of water pans are positive, with strong statistical significance. Pastoral communities derive a positive utility from the construction of water pans in the wet season grazing areas, which are areas far from the permanent water points. Rapid runoff during the rainy season frequently results in a high proportion of water in the county not being utilized, or even becoming destructive. Water scarcity is therefore the biggest constraint to sustainable livelihoods for these communities, who depend largely on livestock as their main source of livelihood. Harvesting rainwater where and when it falls in the water pans presents opportunities to address both water scarcity and soil degradation at a local level. The addition of more water pans will, therefore, benefit the community in addressing the challenges of water shortages; hence, a higher proportion of the population shows a positive preference for the construction of water pans.

The pastoral communities recognize the fact that regulation of grazing by designating wet and dry season grazing reserves is important as an adaptation strategy to the frequent dry spells. This is shown by the positive and significant parameter attribute for a grazing ban near permanent water points during the peak of the wet season to

reserve pasture for dry season grazing and the opening of migratory corridors. This attribute was intended to reduce pressure around the water points during the wet season. During the wet season, there is usually plenty of pasture for animals right across the area. Animals can therefore graze at a distance further from the water points and reserve areas near the water points for dry season use. Reserving these areas when the distant areas have enough pasture to sustain the animals is therefore vital in ensuring that in the dry spells the animals come near to the water points and find some pasture. Migratory corridors are to be designated to allow reciprocal access to the dry season grazing reserves to avoid conflicts with the settled agro-pastoralists in the area. A positive utility can be derived from this attribute when there is a strong traditional governance system that can ensure sustainable management of the grazing areas with equitable benefits for all. This is because the community headmen can be held accountable for their decisions and actions with regards to governance of these areas.

Much of the land in the study area is governed as commons with a set of rules and regulations, created and enforced by the traditional council of leaders. This was evident in the preservation of watering points in areas where proper use and management was guided by traditional leaders with sanctions and penalties in the form of money or in kind (usually animals) for violations of community bylaws. Leveraging such institutions will greatly help in ensuring that communities have enough pasture near the water points in the dry season grazing reserves. As noted by Robinson and Berkes (2011), traditional governance systems that are well facilitated, strengthened and properly linked with other governance structures ensure proper management of the natural resources. When communal governance structures are strong they are normally able to amicably deal with resource use, conflict and management of common resources such as water pans and grazing reserves (Robinson and Makupa 2015). Therefore, supporting effective management institutions for water and pasture resources in Tana River County would enable pastoral communities to derive a significant utility from the dry season grazing reserves accessed through migratory corridors.

The negative sign for the parameter estimate for low biomass threshold shows that the pastoralists derive a negative utility from a very low threshold to stop grazing, with a very high proportion of the respondents placing a negative value on it. A low threshold means high grazing pressure, in this regard; pastoralists are to ensure that grazing livestock assert impact on the pasture and soil for the shortest time possible and allow ample time for the grazed pasture to regenerate, as the grazing animals are moved from one place to another without affecting the regrowth of the defoliated forage. A very low threshold is likely to affect the regrowth of biomass, leading to overgrazing. The pastoral communities know that keeping animals in one area for a continued period of time affects the re-establishment of the defoliated pasture. High frequency of livestock grazing invariably leads to a decline in the plant's productivity, root biomass and vigor (Kamau 2004), particularly in species that are less tolerant to high grazing intensities (Metera 2010). This results in low survival of palatable plants due to competition from less preferred plant species (Kioko, Kiringe, and Seno 2012) leading to colonization by highly competitive and tolerant plant species (Sternberg *et al.* 2000).

The ability of plants to replace tissues lost through grazing and withstand continued defoliation is a function of the rate at which stored carbohydrates are utilized during the dormant or slow-growing season and subsequently replenished during a rapid regrowth period (Adler, Rath, and Lauenroth 2001). This above-ground plant growth

dynamic is transmitted to the roots, as root growth declines when plant shoots are heavily defoliated because most of the carbohydrate reserves are mobilized and the leaf surface, which has the photosynthetic capacity, is limited after being grazed upon (Holechek 2001). Therefore, management practices must ensure a proper grazing threshold to avoid degradation. The pastoral community would, therefore, not prefer a grazing practice that would likely lead to degradation of the grazing fields; hence the observed negative utility.

Greater biomass yield and water levels are the outputs of good grazing management practice. Having more water points, preventing degradation and overgrazing and preserving dry season grazing area will have a positive effect on biomass yield and water availability. This will benefit the community and provide pasture and water across the seasons. The parameter estimates for both water and forage are positive and strongly significant, which means that pastoral communities derive a huge positive utility from both biomass and water. Drylands are predominantly used for livestock production, mainly through pastoralism. Movement of livestock herds is a central component of land management (Galvin 2009). However, traditional mobility within the pastoralist system of the study sites has been compromised by declining access to water and forage resources. This undermines the ability of the communities to cope with the challenges of a complex and dynamic dry land system. The associated natural pastures are experiencing rapid degradation, thus reducing their contribution to livestock feed. Forage and water are, therefore, of significant value to pastoral communities, hence positive utility.

4.2. Economic values of grazing management attributes

The estimated pastoral communities' marginal WTP for water and biomass were the highest in the ranking of the attributes, which shows that pastoral communities obtain a high welfare benefit from adequate water and forage for their livestock. The economic value of any good or service is measured in terms of what consumers are willing to pay for the commodity, less what it costs to supply the commodity (Westernberg 2016). The high marginal WTP for water and biomass therefore shows the great economic value attached to them, since for environmental goods and services, such as rangeland ecosystems, the costs of supply are almost zero, so the consumers' WTP for an environmental resource is usually considered the net value of the resource (Favretto *et al.* 2016; Kelemen *et al.* 2014). The basic premise is that ecosystem services arise, either intentionally or unintentionally, from the conservation practice and can have either a positive or a negative value (Mukama 2010; Lambert 2003). The scarcity of water, which seems to be a recurrent problem in Tana River County, was reported to force people to use similar water sources for both livestock and human consumption, regardless of poor quality. As a result, milk yield differs significantly between dry and wet seasons. Fluctuations in milk yield exhibited in higher milk production in the wet season, as compared to the dry season, were directly related to scarcity of forage and water resources coupled with energy expended in searching for forage resources. Thornton and Herrero (2010) reported that poor feed quality leads to poor rangeland productivity in terms of meat and milk production. This explains the high economic values attached to forage and water.

The willingness to accept (WTA) compensation for a welfare loss if a low grazing threshold is tolerated in grazing management can be attributed to the negative utility

of overgrazing. A low threshold to stop grazing would allow animals to over utilize pasture in a given grazing site for a long period of time, which is detrimental to the survival and production of the plants (Steffens *et al.* 2008). Proper utilization increases forage quality by creating environmental conditions that deter the survival of invasive weed species, while favoring recruitment and survival of palatable forage/browse species.

Oba, Vetaas, and Stenseth (2001) observed that when an area is severely utilized to the extent that it does not allow regrowth after defoliation, undesirable forage species tend to upsurge at the expense of more palatable forage species, which results in an economic loss. Herbivores, therefore, essentially affect the composition and productivity of plants through change of plant nativity, recruitment and mortality (Adler, Raff, and Lauenroth 2001), and this may affect the functioning of the community and its structure (Fortin *et al.* 2003). An ecosystem may resist changes produced by grazing, up to a certain threshold beyond which further changes are rapidly accentuated by stochastic abiotic factors such as rainfall. These account for the negative utility derived from the low threshold, a proxy of high grazing pressure, and thus WTA compensation due to overgrazing. As indicated by Fraser (2003), given alternative investment opportunities, pastoralists would express low preference for compensation programmes that they might consider to be less cost-effective in the use of existing resources. Pastoralists would, therefore, prefer to invest more in enterprises that they perceive to offer high output at lower cost.

5. Conclusion

Deterioration of rangelands has a negative impact on livestock production and subsequently on the welfare and livelihoods of the people who depend on livestock in addition to the environment. The study sought to determine the economic value of grazing management practices in pastoral areas using discrete choice modeling.

The results show that pastoralists would prefer to have a grazing management system in which: there are enough water pans to harvest and store water; there is a dry season grazing reserve; and overgrazing is limited to avoid degrading the grazing fields and one with enough forage yield and water for the animals. Pastoral communities derive greater utility from management practices that allow reciprocal access to pasture and water across the wet and dry seasons. Because livestock production is the viable source of livelihood for pastoralists in tropical rangelands, they are willing to pay more in order to have enough water and pasture for their animals. The grazing management practices should, consequently, include these features to enhance its acceptability.

Therefore, to improve resilience to droughts and to enhance livelihood opportunities, investments in water provision and pasture development are essential, as a strategy to promote better use of land, especially by pastoralists. This can be done through strengthened traditional institutions that are facilitated and properly linked with other governance structures in order to ensure proper management of the natural resources that guarantee adequate water and pasture in non-equilibrium ecosystems. The various management practices put in place to protect rangelands from degradation and promote their sustainable management can, therefore, generate higher levels of productivity when there is comprehensive information on the economic and social value of the impacts of these management practices in rangelands.

Disclosure statement

No potential conflict of interest was reported by the authors.

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