Land Use Policy 147 (2024) 107364

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Structured decision-making shows broad support from diverse stakeholders for habitat conservation and restoration in Kenya's Central Highlands

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ARTICLE INFO

Keywords:
Connectivity
Ecosystem services
Land-use change
Local communities
Kenya
Multi-criteria decision analysis

ABSTRACT

The need for targeted restoration in regions where ecosystem integrity has become compromised is now widely recognised. Local community views, alongside those of other stakeholders, should be incorporated into transparent decision-making to ensure conservation/restoration activities are successful. We used a structured decision-making approach, working with stakeholders and local communities, to pose and answer the following question for Kenya's Central Highlands: "*what future land-use options* [2030] *are feasible for the study region, which is most preferable, how does this vary between different stakeholder groups, and what values drive these preferences?*". We engaged with 51 individuals from six stakeholder groups (*Big Farms*, *Conservationists*, *Counties*, *Forest Users*, *Pastoralists*, *Smallholders*). As individuals, the stakeholders held significantly different values for provisioning, cultural, regulation and maintenance ecosystem services. However, following consensus-building activities within the six groups, shared values and perspectives emerged. The future land-use option of habitat conservation/restoration was preferred by the majority of stakeholder groups, although one (*Big Farms*) favoured increased plantation forestry. Water resource management was also prioritised consistently. By using structured

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https://doi.org/10.1016/j.landusepol.2024.107364
Received 10 December 2022; Received in revised form 15 August 2024; Accepted 10 September 2024
Available online 23 September 2024
0264-8377/

decision-making, we demonstrate that ecosystem restoration is compatible with the views and values of smallholders and forest users, as well as those with a direct interest in conservation. Structured decision-making processes can facilitate stakeholders with disparate views to work towards a consensus regarding future land-use options, aiding environmental planning and implementation.

1. Introduction

Human impacts on the natural environment are profound (Ruckelshaus et al., 2020; Steffen et al., 2015) and increasing worldwide, with anthropogenic activities driving contemporary biodiversity loss and eroding ecosystem functioning (Ellis et al., 2021; Green et al., 2020; Williams et al., 2020). While maintaining and protecting intact habitats is vital for biodiversity conservation and ecosystem service delivery (Allan et al., 2020; Dinerstein et al., 2020), the need for targeted restoration in areas where ecosystem integrity has become compromised is also becoming more widely recognised (Chazdon and Brancalion, 2019; Leclère et al., 2020). Indeed, the Convention on Biological Diversity's 'Post 2020 Zero Draft' outlines global agreement on future strategies (Convention on Biological Diversity, 2020), emphasising the need "to put biodiversity on a path to recovery" before 2030. This imperative is further augmented by the 'United Nations Decade on Ecosystem Restoration', which aims to prevent, halt and reverse the degradation of ecosystems worldwide (UNEP, 2021).

If ecosystem restoration is to be successful, then engaging with communities that live within the target landscapes is essential (Austen et al., 2023; Chazdon, 2019; Dodev et al., 2020; Erbaugh et al., 2020). Such local communities are often politically and geographically marginalised, so it is important to ensure that impacts on livelihoods from restoration are minimised or avoided (Bond et al., 2019; Coleman et al., 2021; Pritchard, 2021). Local community views should therefore be accounted for in decision-making, alongside the standpoints of other actors from the public and private sectors (Chazdon and Brancalion, 2019). Transparent and equitable land-use decision-making should benefit those who will be most affected by the outcome (Guerrero et al., 2018). Furthermore, by ensuring local community support for, and stewardship of, conservation and restoration activities, such projects are more likely to be effective in perpetuity (Coleman et al., 2021; Maxwell et al., 2020).

Encouraging stewardship of conservation and restoration projects is especially important in regions such as Sub-Saharan Africa, where a large proportion of extant terrestrial megafauna reside (Barlow et al., 2018; Ripple et al., 2016). Megafauna need large, connected landscapes to support seasonal movements. However, they exist within rapidly transforming human-modified landscapes (Ellis et al., 2021) where structural connectivity between PAs is particularly constrained (Saura et al., 2018; Ward et al., 2020). Additionally, Sub-Saharan PAs are often ineffective. This is due, in part, to underfunding (Lindsey et al., 2018; Coad et al., 2019). Conservation initiatives have, in some locations, been hampered by protectionist, exclusionary and militarised practices against local communities that have fostered resentment and antipathy (Duffy et al., 2019), increasing the likelihood of conflict and failed implementation (Zafra-Calvo and Geldmann, 2020).

One way to address potential conflicts is with structured decision-making. This approach allows for a careful and organised analysis of a problem, providing an audit trail of how a decision was made (Hemming et al., 2022). It is appropriate for engaging diverse stakeholders in conservation and restoration planning because it does so through a transparent and defensible process of identifying and evaluating the values that underlie the decisions (Esmail and Geneletti, 2018; Loos et al., 2023). The recognition of distinct perspectives also highlights the trade-offs inherent within choices, facilitating decision-making that balances conservation and restoration with other social and economic goals (Hemming et al., 2022). Moreover, it often helps to garner support from local communities by being explicit about the benefits they should receive from conservation and restoration plans (Mustajoki et al., 2020).

A multi-criteria decision analysis (MCDA) is a structured decision-making tool that can systematically and transparently examine stakeholder values and preferences for alternative decision options (Esmail and Geneletti, 2018). MCDAs are widely-applied in healthcare (Gongora-Salazar et al., 2023) and wider environmental decision science (Cegan et al., 2017; Jamwal et al., 2021; Petropoulos et al., 2023). In this paper, we report on a MCDA we conducted within Kenya's Central Highlands, where ecosystem integrity is threatened (Government of Kenya, 2017). The study region is a complex socio-ecological system characterised by diverse land-uses, ethnicities, industries and habitats (Kiteme et al., 2008). Our specific objective was to work with stakeholders to pose and answer the following question: "*what future land-use options are feasible for the study region, which is most preferable, how does this vary between different stakeholder groups, and what values drive these preferences?*" This is the first time that structured decision-making has been used to examine future land-use options in this region.

We evaluate future land-use options, following a national moratorium on timber harvesting within state-run PAs that was enacted after illegal clearing occurred within Mount Kenya's PAs (Government of Kenya, 2018a). This policy follows on from two previous moratoria (Emerton, 1999; Vanleeuwe, 2004), highlighting that the underlying land-use governance issues were not properly addressed in the past and that equitable and transparent decision-making would be constructive moving forwards. All stakeholder groups were represented at each step in the structured decision-making process, assessing and quantifying preferences for the ecosystem service benefits the groups are likely to receive from the range of future land-use options. The general objectives of the process were to recognise the multiplicity of stakeholder perspectives, highlight which outcomes were baseed on shared values, and challenge potential conflicts between conservation goals and local interests. By grounding the MCDA within the context of specific policies and their real-world implications, we offer insights into the compatibility of ecosystem restoration with the views and priorities of all stakeholder groups, including traditionally marginalised groups like pastoralists, smallholders and forest users.

2. Materials, methods and results

The Materials, methods and results sections are presented together, reflecting the iterative and participatory nature of structured decision-making.

2.1. Study region and stakeholder-defined study area

Kenya's Central Highlands are ecological important, culturally heterogeneous and are a region where people are striving actively to engage with ecological restoration and enact sustainable land management practices. Consequently, they serve as an illustrative case study that can offer valuable insights applicable to comparable regions in Sub-Saharan Africa grappling with similar land-use dilemmas. Our stakeholders defined the study area boundary within the region (see subsection 2.2.1). The resulting 4198 km^2 area centred on the PA area complex of Mount Kenya and the remaining habitat linkages to the contiguous PAs of Aberdare, Laikipia and Samburu (Fig. 1).

Mount Kenya is a World Heritage Site, designated due to its high biodiversity, cultural and aesthetic values (Kiteme et al., 2008). The rest of the study region is a network of state, private and community run PAs, linked by a matrix of mixed land-use strategies. The highlands stretch out north, west and south from Mount Kenya and contain the well-watered and fertile ancient lava flows of the Laikipia Plateau. Vegetation cover is defined largely by altitude (Konecky et al., 2014), but also driven by the region's climate, with its history of variable rainfall and temperatures (Schmocker et al., 2016). Indeed, the climate follows a bimodal rainfall pattern that is becoming more variable and intense, with highs of 2,000 millimetres per year in the alpine zone and south-eastern forests of Mount Kenya, and lows of 300 millimetres in the northwest near the settlement of Archer's Post (Schmocker et al., 2016).

The PAs contain a variety of habitat types, including Afromontane forests and Afro-alpine moorlands, that provide habitat for species of conservation concern, such as an estimated population of over 2000 forest-dwelling African bush elephants *Loxodonta africana* (Vanleeuwe, 2004) and local/Afromontane endemics (Musila et al., 2019; Riggio et al., 2019). Much of the original 'protected' forest has been degraded or converted to agriculture or silviculture (Emerton, 1999; Vanleeuwe, 2004), as has the surrounding forest-savannah mosaic (Kiteme et al., 2008). Nonetheless, the matrix contains fragmented pockets of higher quality natural habitats within additional state-run PAs and wildlife conservancies. The latter are land parcels owned and managed by private landowners or a community for wildlife conservation and other compatible land-uses that improve livelihoods, such as ecotourism (Government of Kenya, 2018b).

An estimated 500,000 people live within the study region, with 5.2 million inhabiting the wider seven counties (Rose et al., 2019). The region supports local livelihoods through domestic and international tourism (Steinicke and Neuburger, 2012), an industry that provided 9 % of the annual gross domestic product nationally before the COVID-19 pandemic (Turner, 2017). The region also provides other ecosystem services, notably as a water catchment, regulating water flows for domestic, agricultural and industrial uses for a third of Kenya's people across a half of the country's land surface (Gathaara et al., 1999). Additional livelihood benefits are provided from agriculture and silviculture, with these industries employing over half the labour force at a national-scale and contributing to over a fifth of Kenya's gross domestic product (Ulrich et al., 2012; Zaehringer et al., 2018).

2.2. Structured decision-making process

Throughout the structured decision-making process, we worked with stakeholders, including local communities and organisations that had either the power to shape the problem we were addressing, or were affected by the outcomes of any decisions made (Fig. 2). Ethical approval was given by the University of Kent School of Anthropology and Conservation Research Ethics Committee for the semi-structured interviews and expert elicitation process (2-PGR-18/19) and remaining multi-criteria decision analysis steps (8-PGR-19/20). Research permits were provided by the Kenya Forest Service (RESEA/1/KFS/VOL.III (97)) and Kenya Wildlife Service (KWS/BRM/5001).

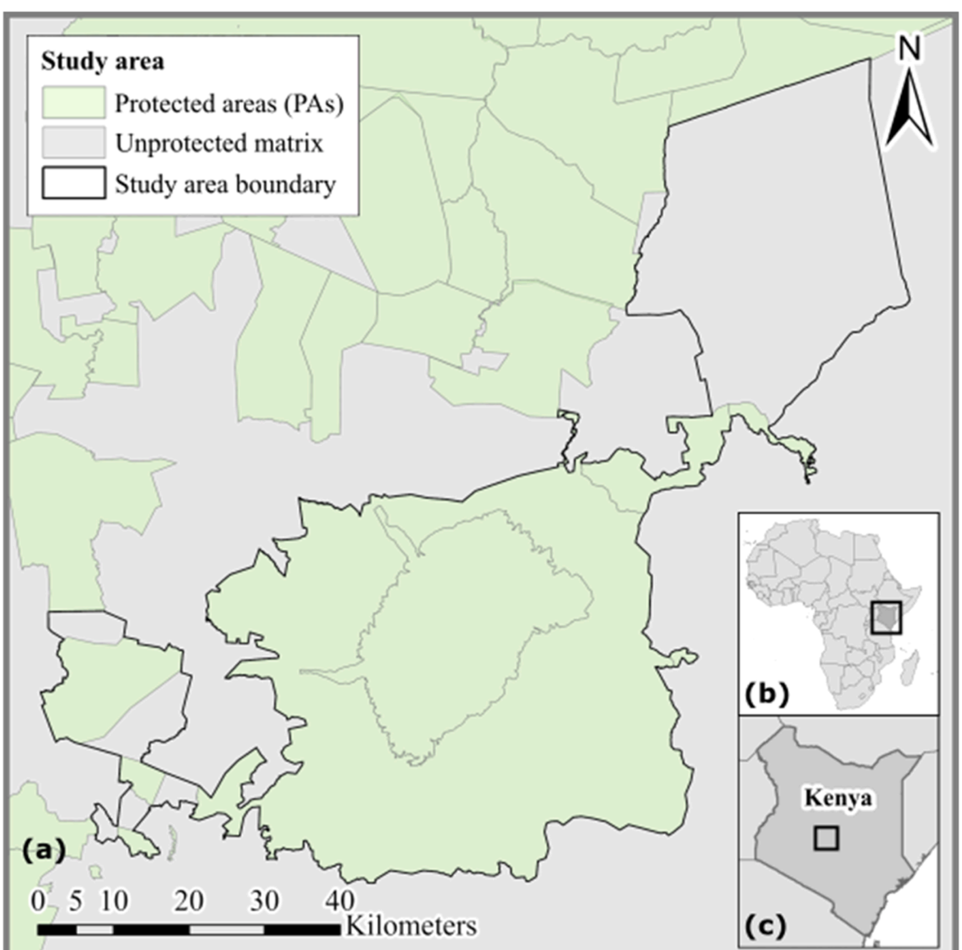

Fig. 1. The stakeholder-defined study area (outlined in black) for the multi-criteria decision analysis (MCDA) is displayed in (a). The area comprised the Mount Kenya protected areas (PAs) and sections of the surrounding matrix that connect with the contiguous PAs of Aberdare, Laikipia and Samburu. Inset map (b) shows the location of Kenya within Africa and (c) indicates the location of the study region within Kenya.

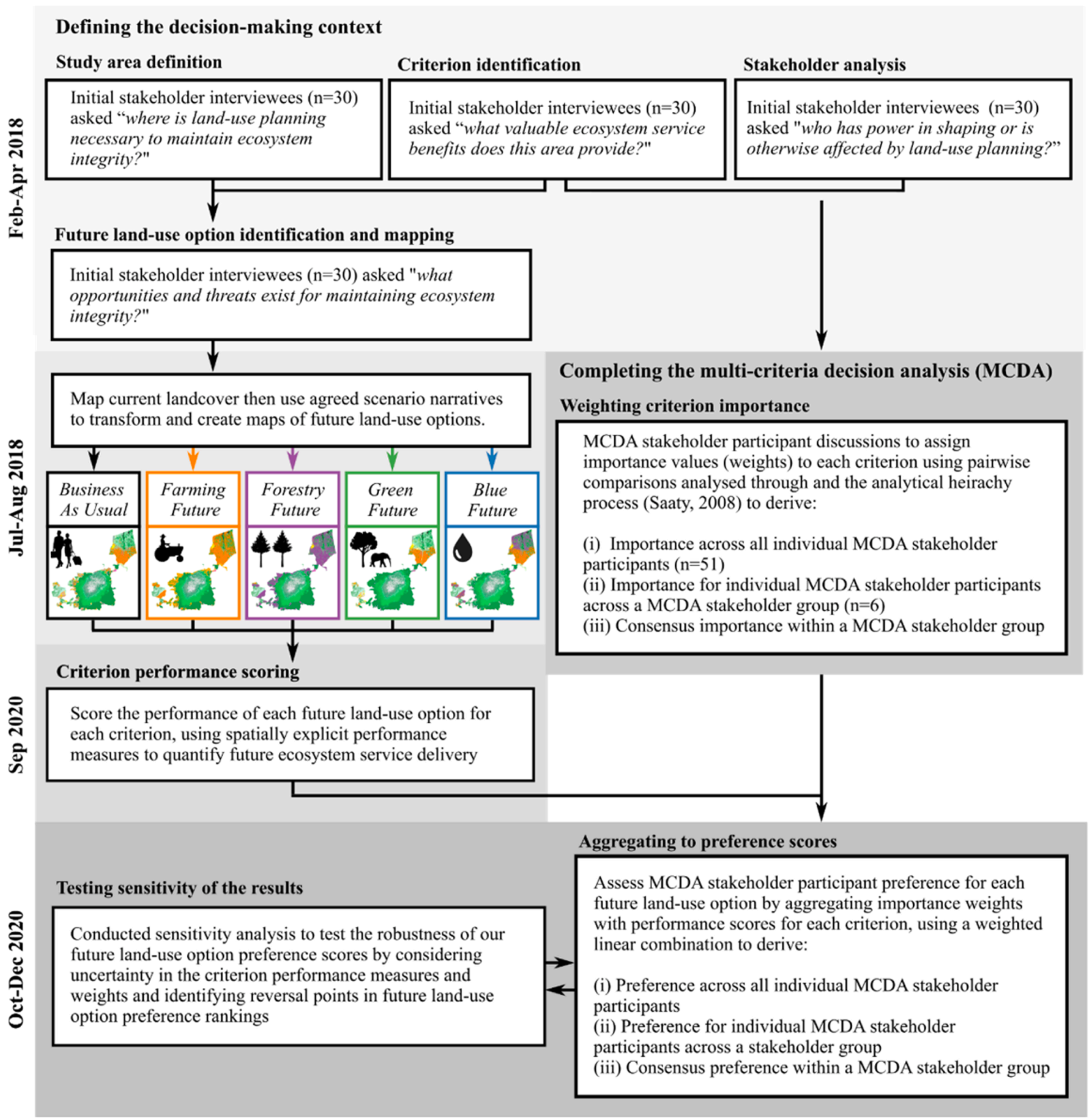

Fig. 2. The methodological steps used in the structured decision-making process, from defining the decision-making context to completing the multi-criteria decision analysis (MCDA). The specific objective was to work with stakeholders to pose and answer the following question: "*what future land-use options are feasible for the study region, which is most preferable, how does this vary between different stakeholder groups, and what values drive these preferences?*". The grey shading indicates the timeline for the process.

2.2.1. *Defining the decision-making context*

We used semi-structured interviews (face-to-face; time range for each interview: 50–90 minutes) to determine the decision-making context for the MCDA (Fig. 2). We used a mixed approach to recruiting initial stakeholder interviewees to reduce the biases arising from using a single method. Initially, we worked with the Mount Kenya National Park warden, the senior scientist from Kenya Wildlife Service and three senior staff from a locally-focussed non-governmental conservation agency. These organisations have a strong influence and interest in land-use decision-making (Supplementary Information A; Figure A.1). We then used snowball sampling, where individuals interviewed suggest further potential interviewees. Snowball sampling is most effective at accessing hard-to-reach groups but might over-represent similar individuals and perspectives (Sadler et al., 2010). Therefore, we additionally used a stakeholder interest-influence matrix (Reed et al., 2009; Figure A.1) to help us consider different types of organisations and local community representatives that should be part of the structured decision-making process. Consequently, our initial stakeholder interviewees included farmers, foresters, water resource managers and researchers, as well as national and county government officials from ministries/agencies responsible for land-use and environmental planning, from 21 organisations (Supplementary Information A). We stopped conducting interviews after 30 had been completed, as responses reached saturation and no new information was reported across the cohort.

During these initial stakeholder interviews (conducted by GEMG), we asked each individual a series of open questions, followed by verbal prompts, to: (i) verify that they understood and agreed with the question being posed; (ii) define the extent of the study area and its boundaries to be considered in the MCDA; (iii) identify the ecosystem service benefits relevant as 'criteria', which are the objectives of the decision-making process (Esmail and Geneletti, 2018); (iv) ascertain the stakeholders within the study area; and, (v) identify and map distinct future land-use options. We coded the interview transcripts using NVivo 12 software (QSR International, 2018) and analysed them using grounded theory (Charmaz and Belgrave, 2015). After all the interview transcripts had been analysed, we shared the findings with initial stakeholder interviewees (via email and video calls) for feedback and validation. This was done to ensure that they unanimously agreed on the decision-making context within which the MCDA would occur.

Kenya's Central Highlands are a fragmented landscape (Didier et al., 2011; Kiteme et al., 2008). Retaining and restoring landscape connectivity, using elephants as a proxy for broader biodiversity, is a major focus of land-use planning (Bastille-Rousseau and Wittemyer, 2020; Evans and Adams, 2016; Green et al., 2018; Ihwagi et al., 2019). We, therefore, asked the initial stakeholder interviewees to decide on the extent of the study area and its boundaries within the region, based on where they felt it was necessary to maintain ecosystem integrity using elephant movements as a proxy for wider species movements. They felt that the study area should cover where elephants still move within and between PAs and/or where interventions to preserve or restore habitats are being considered. They delineated the area as the PA complex of Mount Kenya, plus sections of the surrounding matrix of communally- and privately-owned lands that connect with the contiguous PAs of Aberdare, Laikipia and Samburu (Fig. 1).

We engaged the initial stakeholder interviewees in a discussion about the ecosystem service benefits and values they derive from within the study area. They were prompted to talk through what was important to them as individuals and the communities within which they work and live. The responses were used to identify the criteria for our MCDA. These were finalised based on initial stakeholder interviewee feedback so they comprehensively captured the diverse values that stakeholders raised, with a particular focus on ensuring that the values that local communities hold were fully represented (Mustajoki et al., 2020). The criteria were named using terminology that was understandable across our initial stakeholder interviewees, but were grouped according to the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin-Young, 2018). In total, the initial stakeholder interviewees identified 13 criteria, consisting of six provisioning, three cultural and four regulation and maintenance ecosystem services (Table 1).

We asked the initial stakeholder interviewees to identify all pertinent stakeholders within the study area. They identified 36 stakeholder organisations in total (Supplementary Information A). This guided participant recruitment for the remainder of the MCDA, with all 36 organisations represented in the structured decision-making process. The stakeholder organisations were subsequently placed into 13 categories according to their operational remit (Figure A.1), before being classified into six distinct stakeholder groups: (i) large scale agricultural and horticulture operators (hereafter '*Big Farms*'); (ii) conservation practitioners and ecotourism operators ('*Conservationists*'); (iii) county government officials ('*Counties*'); (iv) forest resource users ('*Forest Users*'); (v) downstream pastoral communities ('*Pastoralists*'); and, (vi) smallholder farmers ('*Smallholders*').

We asked the initial stakeholder interviewees about current and future land-uses, and the opportunities and threats for maintaining ecosystem integrity. In doing so, we could then identify and map future land-use options as the alternative choices to be evaluated through our MCDA (Esmail and Geneletti, 2018). The discussions were informed and bounded by policy constraints (e.g. land-use policies on what was permitted within PAs and within riparian land) to ensure they captured possible futures for the year 2030 (Government of Kenya, 2007, 2018a). Future land-uses identified by the initial stakeholder interviewees included agriculture (mentioned by n=12 interviewees), silviculture (n=11), biodiversity conservation and landscape connectivity land-uses (n=13), and water resource conservation (n=12). From these five themes, we developed a suite of future land-use options that were described in narrative form and refined via iterative email and video call feedback with the initial stakeholder interviewees. The initial stakeholder interviewees confirmed that our final future land-use options captured distinct, divergent and plausible scenarios (McKenzie et al., 2012; Peterson et al., 2003). The five future land-use options were:

(i) *'Business As Usual',* which involved the planned harvesting and replanting of exotic timber plantations, plus agricultural expansion outside of PAs in areas where clearing had already occurred.
(ii) '*Farming Future',* where all cultivation and secondary habitats within mixed-use areas of Mount Kenya's PAs and outside PAs were converted to annual crops.
(iii) *'Forestry Future',* where all cultivation and secondary habitats within mixed-use areas of Mount Kenya's PAs and outside PAs were converted to exotic timber plantations.
(iv) *'Green Future',* where all cultivation and secondary habitats within the PAs of Mount Kenya were reforested and 300 m wide grassland elephant corridors were established between PAs.
(v) '*Blue Future',* which captured specific policy recommendations including reforestation of PA exotic timber plantations more than

Table 1
A list of our thirteen stakeholder-derived multi-criteria decision analysis (MCDA) 'criteria', which were the ecosystem service benefits that formed the objectives of our structured decision-making process (Esmail and Geneletti, 2018). The Common International Classification of Ecosystem Services (CICES) code (Haines-Young and Potschin-Young, 2018) for each criterion is provided with the 15 performance measures agreed to score the criterion under each future land-use option.

Criterion (CICES code)	Performance measure scoring approach
Cash crop production (1.1.1.2)	The hectares of mapped area under (i) perennial crops and (ii) exotic plantations during their cash crop cultivation phase
Livestock grazing (1.1.3.1)	The hectares of (iii) exotic plantation and (iv) secondary grassland
Subsistence crop production (1.1.1.1)	The hectares of (v) annual crops
Traditional medicines (1.1.5.2)	The hectares (vi) primary vegetation
Water provision (1.3.X.X)	The Co$ting Nature measure of (vii) realised water provision indexed globally (Mulligan et al., 2010)
Wood for fuel or construction (1.1.5.3)	The hectares of (viii) exotic plantations
Cultural heritage (3.1.2.3)	The hectares of (ix) primary vegetation
Outdoor recreation (3.1.1.1)	The hectares of vegetation given an ordinal multiplier by participants of 1 for (x) primary vegetation and 0.2 for (xi) secondary vegetation
Benefits from tourism (3.1.1.2)	The hectares of vegetation given an ordinal multiplier by participants of 1 for (xvi) primary vegetation and 0.2 for (xvii) secondary vegetation
Biodiversity conservation (2.2.2.1)	The hectares of (xviii) primary habitats and (xix) Linkage Mapper's additional pathway availability (McRae and Kavanagh, 2019), a measure of landscape connectivity
Climate change mitigation (2.2.6.1)	The sum of the Co$tingNature measures of (xii) forest carbon storage and (xiii) forest carbon sequestration (Mulligan et al., 2010)
Soil erosion prevention (2.2.1.1)	The inverse of the WaterWorld measure of (xiv) runoff (Mulligan, 2013)
Water flow regulation (2.2.1.3)	The inverse of the WaterWorld measure of (xv) hillslope net erosion (Mulligan, 2013)

500 m from the boundary, the reforestation of riparian reserves and the relocation of exotic timber plantations outside of Mount Kenya's PAs (Government of Kenya, 2018a).

We next mapped these future land-use options to quantify how they would affect ecosystem service delivery. We first mapped current landcover within the stakeholder-defined study area using a combination of remote sensing and digitising (Supplementary Information B), the results from which were ground-truthed using the African Union's SLEEK project random sampling methodology (African Union, 2016). We then used the landcover changes detailed in the narratives to transform current landcover into maps for each of the five future land-use options (Fig. 3; Supplementary Information B), using R (R Core Team, 2019) and the package 'raster' (Hijmans, 2019).

2.2.2. Completing the multi-criteria decision analysis (MCDA)

Having defined the decision-making context, we completed the MCDA process through 51 individual stakeholder video call discussions (via video call; time range for each interview: 70–120 minutes) and, subsequently, six stakeholder group video call discussions (via video call; time range for each interview: 90–150 min). Four out of 51 MCDA stakeholder participants were initial stakeholder interviewees. All of these discussions were facilitated by GEMG with assistance from CAW, MB, HM and HG . They began with a presentation to familiarise the individual MCDA stakeholder participants with the study purpose, process, and the decision-making context. Additionally, individual MCDA stakeholder participants assigned relative importance weights to each criterion (hereafter 'importance'), and they were also asked to place themselves in the MCDA stakeholder group they most identified with: *Big Farms* (n=7); *Conservationists* (n=14); *Counties* (n=5); *Forest Users* (n=6); *Pastoralists* (n=7); and, *Smallholders* (n=12). During the MCDA stakeholder group video call discussions, the group was asked to reweight criterion importance from a shared perspective, with a quorum of four participants.

The individual and group discussions also allowed the MCDA stakeholders to provide feedback on the methodology we proposed to score the 'performance' of each future land-use option in terms of ecosystem service delivery. We subsequently undertook the performance scoring process using a geographic information system (GIS) and the maps for each future land-use option. We then aggregated the importance weights of each criterion with their relevant performance scores for each future land-use option creating preference scores, hereafter 'preference'.

2.2.2.1. Weighting criterion importance. The relative importance of each criterion was weighted by MCDA stakeholders during the individual and group consensus building discussions. Two decision models were used to do this. In the first, the MCDA stakeholder participants used a ranking and relative weighting technique (Roszkowska, 2013). For this, criteria were placed in order of descending importance and then assigned a numerical importance value as a percentage. In the second, the MCDA stakeholder participants weighted each criterion using pairwise comparisons, where they signified the importance of each criterion relative to the others, attributing values from equal to extreme preference along a nine-point scale. This was analysed using the analytical hierarchy process (Saaty, 2008) and consistency ratios, a measure of the consistency of participant judgements when compared to random choices, tested using the R package 'ahpsurvey' (Cho, 2019).

During the weighting process, the individual MCDA stakeholders were regularly reminded that the importance values they gave should relate to future ecosystem service delivery in 2030. In the individual MCDA stakeholder participant discussions, it was stressed that the 'importance' was from their personal perspective. Outputs from all individuals are termed 'importance across all individual MCDA stakeholder participants', whereas the importance individuals assigned from within particular stakeholder groups is termed 'importance for individual MCDA stakeholder participants across a MCDA stakeholder group'. Geometric mean values were calculated for both. We next carried out the consensus building MCDA stakeholder group discussions, where the emphasis was on capturing importance from a shared perspective, with outputs termed 'consensus importance within a MCDA stakeholder group'.

We checked for significant differences in importance values between the two decision models, using a multivariate analysis of variance (MANOVA) and post-hoc discriminant analysis using the R packages 'psych' (Revelle, 2020) and 'candisc' (Friendly and Fox, 2020). No significant differences in weights were apparent between the two decision models. Given the analytical hierarchy process has been found to be more robust and less prone to biases than the ranking and relative weighting approach (Németh et al., 2019), we only present the analyses based on the pairwise comparisons in the manuscript (a comparison of the weights can be found in Supplementary Information C). We also used MANOVA and post-hoc discriminant analyses to test for significant differences in criterion importance between the MCDA stakeholder groups.

Mean importance across all importance across all individual MCDA stakeholder participants (N=51) (Table 2; Fig. 4) was highest for biodiversity conservation, followed by water flow regulation, climate change mitigation and water provision. However, these criteria also had the most variable importance across all individual MCDA stakeholder participants.

Importance for individual MCDA stakeholder participants across a MCDA stakeholder group highlighted differences between the stakeholder groups (Table 2; Fig. 5). Livestock grazing was weighted as significantly more important by *Pastoralists* than other stakeholder groups ($p<0.001$). Similarly, traditional medicines were weighted as significantly more important by *Pastoralists* than *Big Farms*, *Conservationists* and *Counties* ($p=0.016$). Soil erosion prevention was weighted as significantly more important by *Big Farms* and *Counties* than by *Forest Users*, *Pastoralists* and *Smallholders* ($p<0.001$).

Compared to mean importance for individual MCDA stakeholder participants across a MCDA stakeholder group, consensus importance within a MCDA stakeholder group (Table 2; Fig. 5) saw *Big Farms* weight water provision as more than twofold more important and biodiversity conservation as less important. *Conservationists* weighted recreation threefold more important and biodiversity twofold. *Counties* weighted climate change mitigation as twofold more important. *Forest Users* weighted water provision as more important and gave over twofold the importance to climate change mitigation. *Pastoralists* weighted tourism as more important and provisioning services, cultural heritage, outdoor recreation and biodiversity conservation as less important. *Smallholders* gave a fourfold higher importance to climate change mitigation.

Once the weighting was complete, we analysed consistency ratios, a measure of the consistency of individuals' judgements compared to random choices, finding 19 out of 51 participants were below the standard 0.1 thresholds for inclusion (Saaty, 2008). Excluding participants above the threshold did not change the preference rankings (see Section 2.2.2.3 below), so we proceeded with all data. The consistency ratios for the stakeholder groups *Big Farms*, *Conservationists*, *Counties* and *Pastoralists* were below the same threshold.

2.2.2.2. Criterion performance scoring. We scored the performance of each land-use option for each criterion, using spatially explicit performance measures (Table 1) to quantify how each option affected ecosystem service delivery. The initial stakeholder interviewees and individual MCDA stakeholder participants felt that the area of different landcovers was a suitable proxy for nine of the criteria. Landcovers for two criteria, outdoor recreation and tourism, were assigned multipliers agreed through the individual MCDA stakeholder discussions to capture the relative value of primary vegetation compared to secondary

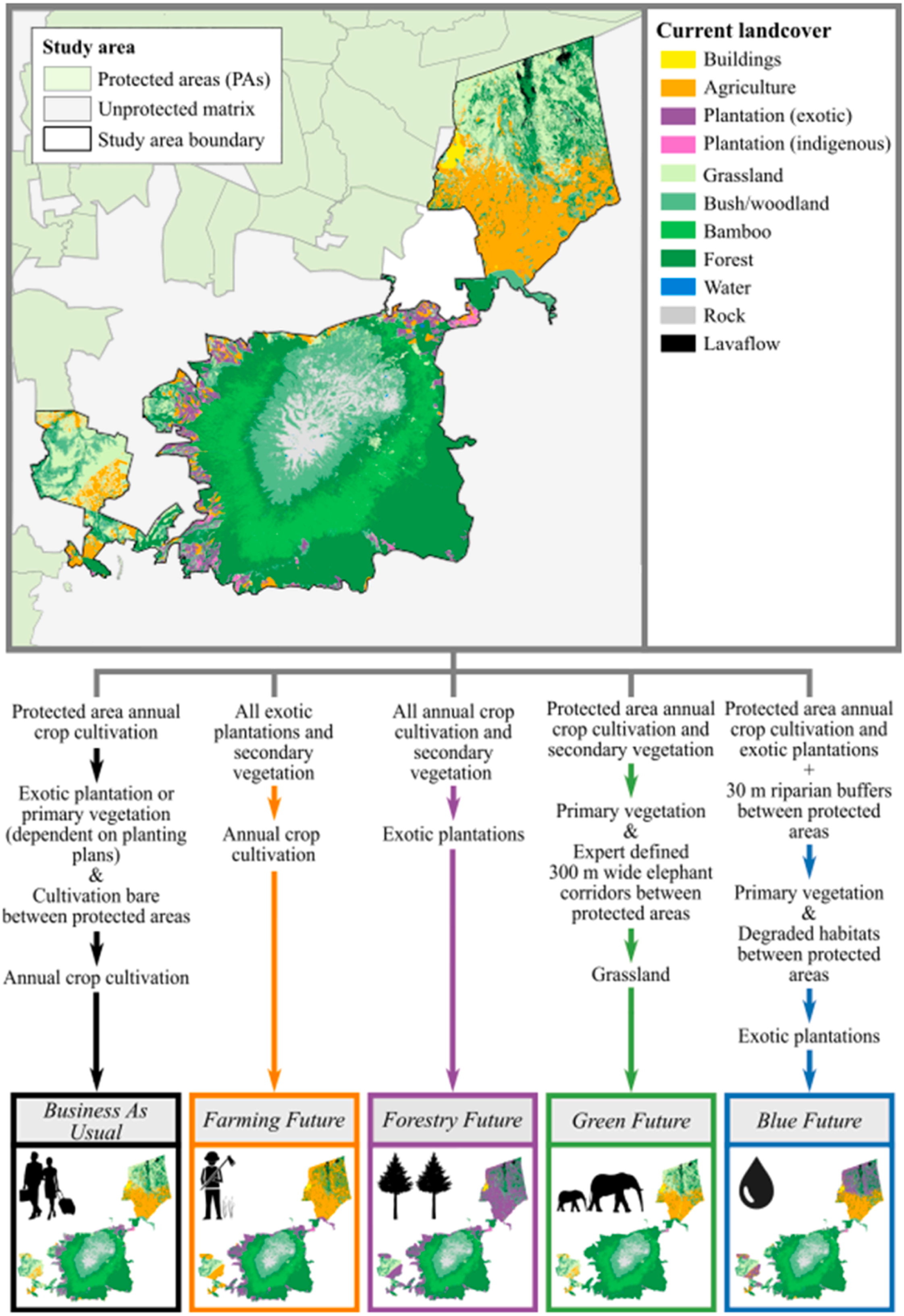

Fig. 3. A representation of how landcover, correct as of January 2018 (top box), was transformed into our five future land-use options to be used in the multi-criteria decision analysis (MCDA): (i) *Business As Usual* (black); (ii) *Farming Future* (orange); (iii) *Forestry Future* (purple); (iv) *Green Future* (green); and, (v) *Blue Future* (blue). Landcover changes only occurred in mixed-used areas of Mount Kenya's PAs and in areas that are not formally protected.

Table 2
Criterion importance (weights) from pairwise comparisons, analysed through the analytical hierarchy process (Saaty, 2008), emerging from the multi-criteria decision analysis (MCDA). Sample size (N and n), mean value (M) and standard error (SE) are shown for all individuals (importance across all individual MCDA stakeholder participants), as well as individuals (importance for individual MCDA stakeholder participants across a MCDA stakeholder group) and consensus (consensus importance within a MCDA stakeholder group) for our six stakeholder groups. Asterisks indicates a significant difference in criterion importance between stakeholder groups, where * is $p<0.05$ and ** is $p<0.001$, based on importance for individual MCDA stakeholder participants across a MCDA stakeholder group (MANOVA post-hoc discriminant analysis).

	All Participants		*Big Farms*			*Conservationists*			*Counties*			*Forest Users*			*Pastoralists*			*Smallholders*		
	Individual		Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus
	N=51		n=7			n=14			n=5			n=6			n=7			n=12		
Criteria	M	SE	M	SE		M	SE		M	SE		M	SE		M	SE		M	SE	
Cash crop production	4.41	0.68	3.03	0.94	8.28	2.92	0.47	0.69	4.35	2.68	11.53	3.55	1.47	0.79	4.00	1.75	1.25	7.64	2.13	1.94
Livestock grazing	4.85	0.81	2.68**	0.85	6.19	2.80**	0.56	0.97	3.10**	0.84	6.56	2.63**	0.75	2.27	14.93**	3.97	10.56	4.47**	0.64	1.00
Subsistence crop production	4.61	0.52	3.13	1.13	2.84	3.36	0.75	2.67	4.10	1.23	5.83	4.22	0.98	1.51	4.57	1.29	2.51	7.36	1.41	2.52
Traditional medicines	2.23	0.30	1.47*	0.32	1.49	0.97*	0.15	0.32	1.42*	0.22	0.65	2.44	0.79	1.05	4.64*	1.32	2.13	2.99	0.64	0.54
Water provision	10.13	0.91	7.93	1.98	21.37	10.61	1.25	7.61	16.38	3.85	6.97	6.86	3.07	13.93	10.07	2.24	9.78	9.90	2.06	4.33
Wood	3.08	0.36	1.65	0.27	5.44	2.44	0.83	1.75	3.30	1.38	6.19	4.31	1.40	4.18	2.86	0.51	3.56	4.07	0.61	0.36
Cultural heritage	4.80	0.84	2.72	0.75	0.98	3.24	0.62	3.04	1.81	0.47	0.81	6.32	2.65	0.19	10.38	4.60	5.28	5.04	1.44	1.51
Outdoor recreation	5.49	0.81	5.67	1.70	2.94	4.23	1.11	15.22	3.11	0.89	4.05	1.92	0.50	1.71	5.20	0.84	2.64	9.80	2.66	1.51
Benefits from tourism	8.81	0.92	11.38	2.23	5.78	7.68	1.27	7.50	8.08	2.45	8.22	5.33	1.19	3.77	12.13	5.23	25.15	8.73	1.00	2.67
Biodiversity conservation	22.25	1.96	26.36	6.69	16.51	24.33	3.57	55.00	18.45	3.96	13.15	35.53	5.50	35.06	14.98	3.57	10.45	16.62	3.63	22.75
Climate change mitigation	10.33	1.43	6.38	2.37	3.94	13.29	3.07	0.45	12.41	7.06	26.66	12.62	6.29	27.65	5.52	1.39	6.67	9.96	1.97	43.74
Soil erosion prevention	7.54	0.77	12.42**	1.85	9.37	9.74	1.49	3.23	11.70**	2.44	3.38	3.57**	1.44	1.48	3.48**	1.19	6.67	4.77**	0.84	7.01
Water flow regulation	11.48	1.10	15.17	3.22	14.87	14.39	2.03	1.55	11.79	2.43	6.01	10.71	3.72	6.39	7.24	2.22	13.35	8.65	2.32	10.11

vegetation, the latter being one fifth of the value of the former. Biodiversity conservation was scored using hectares of primary habitats and a measure of functional connectivity derived from the Linkage Mapper software (McRae and Kavanagh, 2019). The functional connectivity measure was informed by expert opinion on elephant movements across different landcover types and validated by empirical data (Gibbon, 2021). For carbon and water provisioning services, we input the future land-use option maps into Policy Support System's Co$tingNature (Mulligan et al., 2010), which generates forest carbon storage and sequestration measures and realised water provision. Individual MCDA stakeholder discussions highlighted that exotic timber plantations over multi-decade time series might be a net producer of atmospheric carbon, as supported by the literature (Waller et al., 2020). To account for this, we classified exotic timber plantations as grasslands when modelling climate change mitigation (carbon services). For soil erosion and water flow control, we used Policy Support System's Waterworld (Mulligan, 2013) to produce measures of hillslope net erosion and runoff. Finally, raw criterion performance scores (Supplementary Information D) were summed from their performance measures and normalised along a scale of 0–100, with 0 representing the worst level of performance and 100 the best, transforming input data to aid in comparability (GoUK, 2009).

Our future land-use options showed pronounced differences in criterion performance (Fig. 6). *Business As Usual*, by its nature as a counterfactual portraying what would have happened without the intervention of the national moratorium in timber resource extractions within PAs (Government of Kenya, 2018a), had mid- to low-range performance. *Farming Future* performed highest for cash crop production and subsistence crop production, and lowest for all other criteria. *Forestry Future* performed highest for wood products, livestock grazing, water provision, water flow regulation, and soil erosion and low for other criteria, some of which had equal performance to *Farming Future*. *Green Future* performed highest for traditional medicines, cultural heritage, outdoor recreation, climate change mitigation, benefits from tourism and biodiversity conservation with mid- to low-range performance for other criteria. *Blue Future*, by result of it capturing specific spatial zoning recommendations (Government of Kenya, 2018a), performed with high- to mid-range scores across all criteria.

2.2.2.3. Aggregating to preference scores and testing sensitivity of the results. We assessed stakeholder preference for each future land-use option, the decision outcome of the MCDA (Esmail and Geneletti, 2018), by aggregating importance weights with performance scores for each criterion: (i) 'preference across all individual MCDA stakeholder participants'; (ii) 'preference for individual MCDA stakeholder participants across a stakeholder group'; and, (iii) 'consensus preference within a MCDA stakeholder group'. To calculate these, we used a weighted linear combination approach:

$$S_i=\sum_{j=1}^{n} w_j s_{ij}$$

Here, the overall preference score for future land-use option (S_i) was calculated by summing the normalised criterion performance score ($_j$) as an option performance score (S_{ij}), which was then multiplied by the criterion weight (W_j) for all criteria (n).

Mean preference across all individual MCDA stakeholder participants was highest for *Green Future* followed by *Blue Future* (Fig. 7; Table 3). Preference was highest for *Green Future* for 42 individual stakeholders, with the remaining nine preferring *Forestry Future*. *Blue Future* was the second preference for 32 stakeholders. Mean preference for individual MCDA stakeholder participants across a MCDA stakeholder group was also highest for *Green Future*, with the strongest preference amongst *Forest Users*, followed by *Smallholders*, *Pastoralists*, *Conservationists*, *Big Farms* and finally *Counties*. *Blue Future* was the

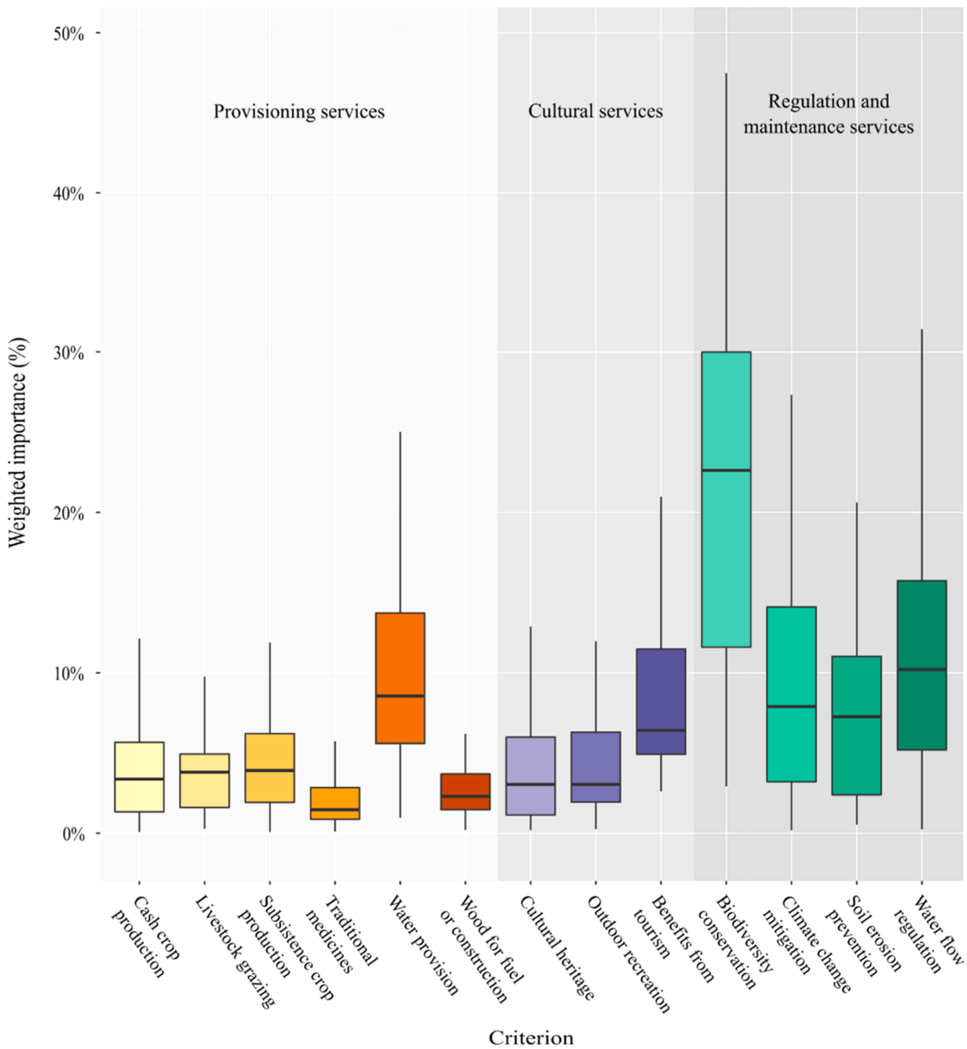

Fig. 4. Criterion importance (weights) across all individuals from pairwise comparisons, analysed through the analytical hierarchy process (Saaty, 2008), emerging from the multi-criteria decision analysis (MCDA). Coloured boxes show the standard deviation, with the central vertical line indicating the geometric mean, and the horizontal black line either side of the coloured boxes represents the range.

second preference for all stakeholder groups, except for *Counties*. Mean preference for individual MCDA stakeholder participants across a MCDA stakeholder group was consistently lowest for *Farming Future*.

Consensus preference within a MCDA stakeholder group was stronger for *Green Future* across all stakeholder groups, with the exception of *Big Farms,* who had the highest preference for *Forestry Future.* Once again, *Business As Usual* and *Farming Future* ranked lowest for all stakeholder groups. Across all three levels of preference score comparison (mean preference across all individual MCDA stakeholder participants, mean preference for individual MCDA stakeholder participants across a stakeholder group, and mean consensus preference within a MCDA stakeholder group), the greatest variability in scores was for *Forestry Future* followed by *Green Future*. We carried out a sensitivity analysis to test the robustness of our future land-use option preference scores by considering uncertainty in the criterion performance measures and weights and identifying reversal points in future land-use option preference rankings. This form of model evaluation is an important step in a MCDA as it provides an understanding of the values that have the biggest effect on the outcome (Delgado and Sendra, 2004; Esmail and Geneletti, 2018). We found the model was mildly sensitive to agricultural, silvicultural and hydrological ecosystem services, which caused switches to occur between *Green Future* and *Forestry Future* being of highest preference (Supplementary Information E).

3. Discussion

3.1. *Moving towards consensus through structured decision-making*

Decisions pertaining to land-use, particularly those that involve prioritising biodiversity conservation and restoration, are often thought to be contentious, particularly when it comes to integrating the interests of local communities (Bond et al., 2019; Coleman et al., 2021; Pritchard, 2021). In large groups, influence and politics can dominate discussions at the expense of less vocal or powerful stakeholders (Maund et al., 2022). We therefore built consensus within our stakeholder groups, rather than trying to do so across all of them, to ensure we gathered a richness of information to inform decision-making and genuine indication of where trade-offs and disagreements might occur. By using such an approach to structured decision-making, we uncovered broad stakeholder preference for habitat restoration and wildlife corridor establishment, as well as the rezoning of forestry activities and prioritisation of water resource management within Kenya's Central Highlands. These preferences were based on an agreement of the importance of biodiversity conservation, climate change mitigation and water-based ecosystem services, which were most valued by *Forest Users, Smallholders* and *Conservationists.* Although in Kenya wildlife corridor establishment is a major focus of national planning (Government of Kenya, 2017), it

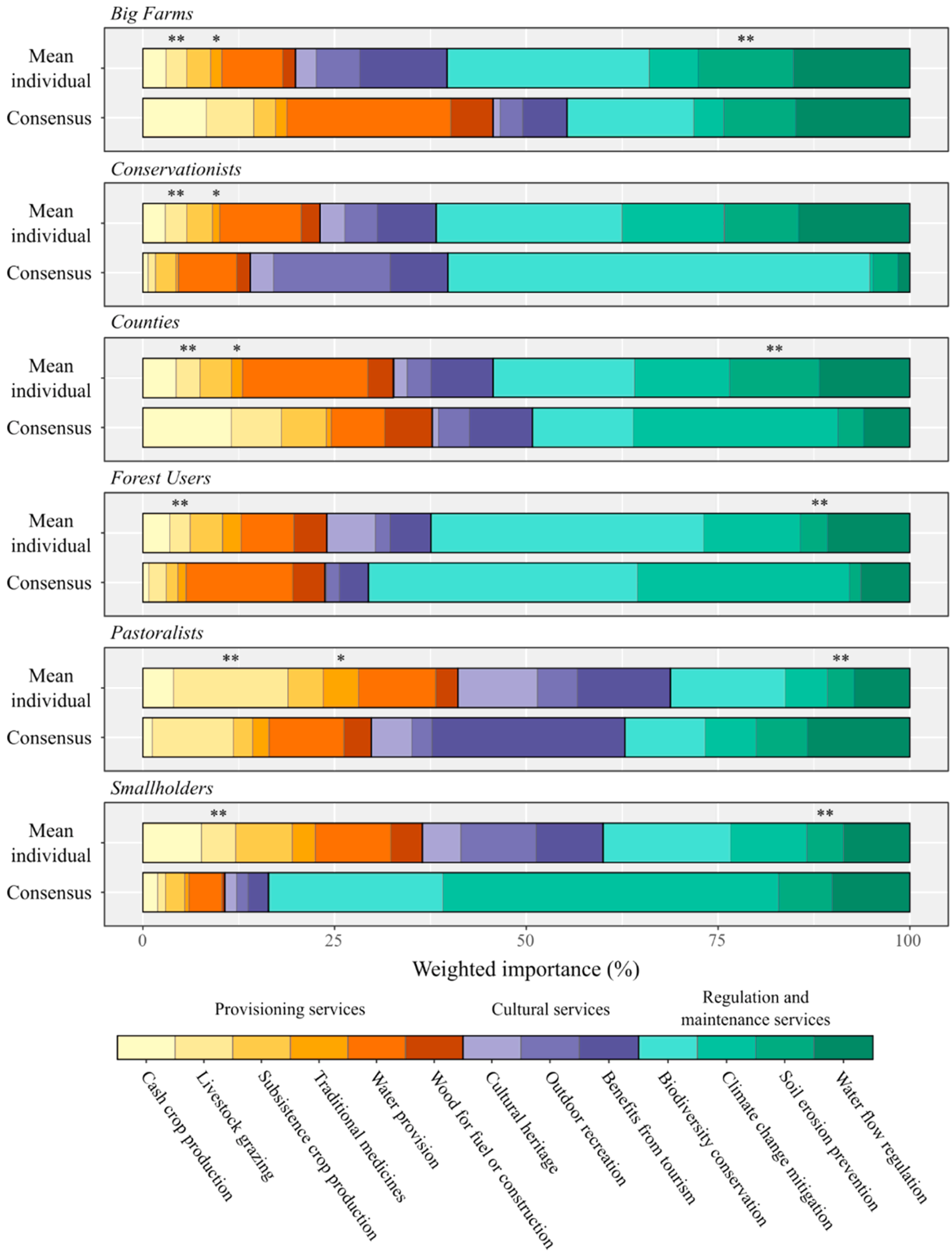

Fig. 5. Importance (weights) for the multi-criteria decision analysis (MCDA), with the mean individual importance for individual MCDA stakeholder participants across a MCDA stakeholder group above and consensus importance within a MCDA stakeholder group below, from pairwise comparisons, analysed with the analytic hierarchy process (Saaty, 2008). Colours show the 13 criteria in the three overarching ecosystem service groups (outlined with black boxes). Asterisks indicate a significant difference in criterion importance between stakeholder groups, where * is $p<0.05$ and ** is $p<0.001$, based on importance for individual MCDA stakeholder participants across a MCDA stakeholder group (MANOVA post-hoc discriminant analysis).

has had limited support from local communities in the past (Kamweya et al., 2012b). Our findings demonstrate that biodiversity conservation and ecosystem restoration are compatible with the views and values of smallholder farmers and forest users, as well as those with a direct interest in conservation.

Only *Big Farms* prioritised a scenario other than biodiversity conservation and restoration. Instead, they preferred the *Forestry Future*, and this switch was because large agribusiness prioritised provisioning services and water flow control. This finding highlights the potential of maintaining water-based ecosystem services when seeking agreement over future land-use scenarios. In our case, large agribusinesses, which depend on reliable sources of water for irrigation, are a dominant actor

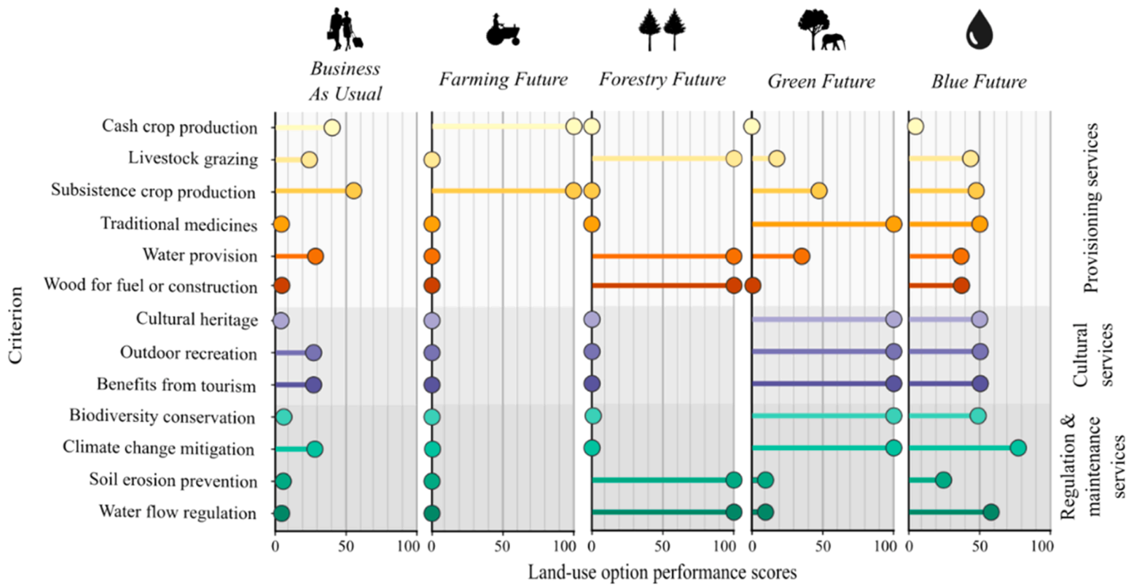

Fig. 6. Performance scores, relative measures of future ecosystem service delivery, for each criterion for the five future land-use options normalised on a scale of 0–100, from worst to best performance (see Supplementary Information D for raw scores).

in the region, and water-based ecosystem services are vital to the livelihoods of all stakeholders (Notter et al., 2007; Sungi, 2018). Forestry is also an important land-use in Kenya's Central Highlands (Emerton, 1999; Kehlenbeck et al., 2011), providing timber and cash crops during plantation establishment, as well as leaving land available for livestock grazing. However, caution in prioritising forestry is needed as exotic plantation establishment within the savannahs and grasslands between PAs would negatively impact biodiversity (Bond et al., 2019) and potentially release the carbon stored in soil (Waller et al., 2020).

Although we uncovered broad consensus for biodiversity conservation and forestry across all stakeholders, the *Green Future* and *Forestry Future* scenarios were also characterised by a large variation in preferences, suggesting underlying differences in opinion regarding how these scenarios might be implemented, or who might be affected. Thus, if either were to be implemented, challenges could arise when it becomes clearer which stakeholders will be directly affected and how those impacts will be felt. For instance, *Forest Users* as individuals across a stakeholder group had the strongest mean preference for *Green Future*, as they would benefit from the expansion of community-led reforestation in the short term. This type of reforestation is currently done in partnership with the Kenya Forest Service and the Mount Kenya Trust (a local NGO) (Mount Kenya Trust, 2018). However, individuals would eventually lose the right to cultivate their land after the trees are established, as well as suffering losses due to reduced plantation forestry with the PAs. Elsewhere such loss of land-use rights has caused increased environmental destruction in retaliation to reduced access and social tensions within and between different aggrieved communities (Witcomb and Dorward, 2009). Implementing the reforestation indicative of *Green Future*, or the forestry expansion in *Forestry Future* would therefore need to be undertaken with awareness of the needs of all stakeholders.

Business As Usual, representing what happened after the two previous moratoria on forest resource extraction (Emerton, 1999; Vanleeuwe, 2004), had a low preference and variation was low. This indicates that ending the current moratorium without rezoning forestry activities within the PAs would not be an outcome welcomed by stakeholders. On the other hand, *Blue Future* consistently ranked as second preference, and variation was low, demonstrating consistent support for the provision of water-based ecosystem services that are associated with shifting plantation forestry to the periphery of the PA complex and expanding reforestation. Downing et al. (2023) found similarly, with stakeholders most appreciating water provision services, but also reporting decreased availability due to over extraction. By emphasising the ecosystem service benefits associated with improved management of montane habitats, including water management, *Blue Future*, therefore, represents a balanced option, likely to garner considerable support across all stakeholder groups (Notter et al., 2007; Viviroli et al., 2007).

3.2. Implications for implementation

Successfully implementing any of the suggested rezoning plans associated with our future land-use scenarios will require management authorities to build on the local support we found to appropriately ensure effectiveness and stewardship. A key consideration will be avoiding human-human and human-wildlife conflict, as this could undermine restoration and conservation goals. Appropriately relocating plantation forestry and reforesting former plantations utilising areas that are of low biodiversity and conservation value for initiatives such as agroforestry would have the potential to increase forest cover and support local livelihoods (Chazdon and Brancalion, 2019; Orsi et al., 2011); something that would align with suggestions made by stakeholders and could thus command considerable support.

Our methodological approach adopted a broad perspective on land-use decision-making, with the aim of gaining a comprehensive understanding of stakeholder preferences across the entire study area, rather than determining specific starting points for implementation. Subsequent evaluations and prioritisations at the catchment level would facilitate effective operationalisation of any rezoning efforts (e.g. Garcia et al., 2018). A spatial MCDA would be a helpful tool in this regard (e.g., Poli et al., 2024), allowing the identification and targeting of sub-catchments that can yield maximum benefits for the population. Using visual mapped outputs can be beneficial in understanding and conveying complex spatial planning decisions to a diverse audience (e.g. Samiappan et al., 2022). Nonetheless, it is crucial to note that the successful application of such approaches depends on continuous stakeholder consultation to incorporate evolving perspectives on different policies. Such iterative engagement ensures the ongoing relevance of the analysis in the dynamic context of decision-making (Carrick et al., 2022).

Our stakeholder discussions raised the underlying challenges associated with implementation. It was felt that the needs of downstream communities (*Pastoralists*) required greater consideration, as upstream water resource management affects them. Stakeholders also stressed the

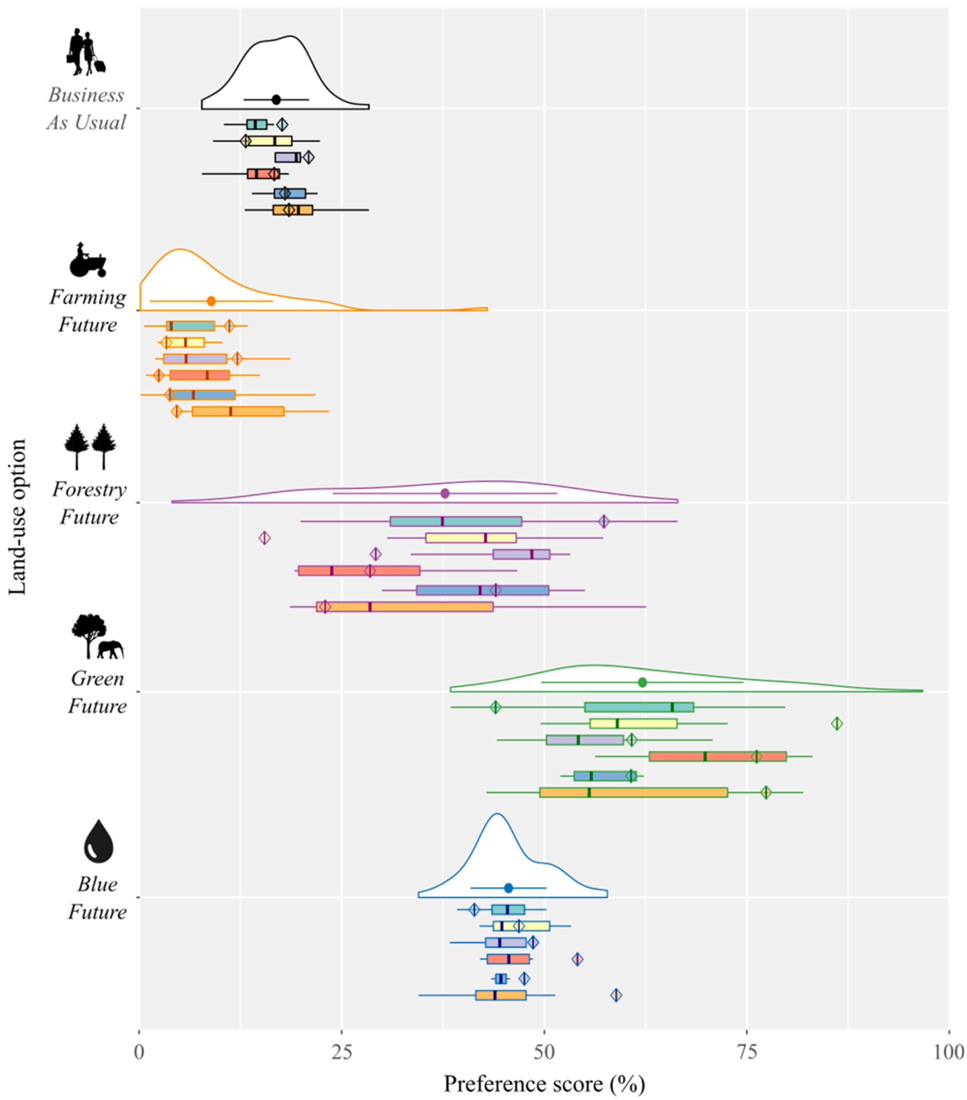

Fig. 7. Multi-criteria decision analysis (MCDA) stakeholder preference scores for the five future land-use options: *Business As Usual*, black; *Farming Future*, orange; *Forestry Future*, purple; *Green Future*, green; *Blue Future*, blue. Horizontal half violin plots show preference value distribution across all individuals (personal values), with the point and line within the white of half violins showing mean and standard deviation. Horizontal boxplots show preferences for preference for individual MCDA stakeholder participants across a stakeholder group (personal values). The diamonds indicate consensus preference within a stakeholder group (shared values): *Big Farms*, green; *Conservationists*, yellow; *Counties*, light purple; *Forest Users*, red; *Pastoralists*, blue; *Smallholders*, orange. See weighting criterion importance section for further details on the different stakeholder values.

economies of scale that influence a landowner's ability to tolerate and mitigate human wildlife conflicts. Large agribusinesses can afford to experience limited crop damage when wildlife moves across their land (e.g. Nyaligu and Weeks, 2013), whereas smallholders cannot (e.g. Kamweya et al., 2012a; 2012b). Payment for ecosystem service initiatives could therefore be a valuable approach to promoting landscape connectivity, not least because they are a more appropriate tool than land purchase or easement approaches in Kenya (Curran et al., 2016). Discussions also occurred centred around where responsibilities for climate change mitigation through reforestation lie. *Smallholders*, *Forest-users* and *Counties* weighted climate change mitigation highly but, during the consensus building stage, *Big Farms* gave this a lower weight, stating that this was the responsibility of the high-income countries. This observation reinforces the findings of other studies that describe how local communities are acutely aware of the severity of the ecological and climate crises, and are on the frontline of responding to it (Agarwal et al., 2019, Bluwstein et al., 2021).

When interpreting our results, it is also important to consider the limitations inherent to such a study. Developing future land-use scenarios always involves simplifying potential outcomes and our approach required making trade-offs between complexity and clarity (Sohl and Claggett, 2013). In the absence of better data, we used relatively crude measures of biodiversity and ecosystem services. Although it is plausible that more resolved data may have improved the overall process, all data were reviewed by the stakeholders who agreed that they were accurate reflections of the on-the-ground situation. We followed a robust process for identifying a diverse array of stakeholders. While the stakeholder groups had different numbers of members, numerical differences in group composition are less important than ensuring that a diversity of views are represented, something that our stakeholder identification process helped to ensure. Finally, the future land-use scenarios assumed that every landowner is willing and able to implement changes on their land. In reality, we know that some individuals may be reluctant about, or incapable of, making these changes, so there is a need for further work to understand barriers to implementation and potentially develop appropriate incentive and/or support schemes were necessary (Chazdon and Brancalion, 2019).

Ensuring a sustainable future for the ecosystems within areas such as

Table 3
Stakeholder preference scores for the five future land-use options from pairwise comparisons, analysed with the analytic hierarchy process (Saaty, 2008). Values show sample size (N and n), mean value (M) and standard error (SE) for individual MCDA stakeholder participants (preference across all individual MCDA stakeholder participants), then individual (preference for individual MCDA stakeholder participants across a stakeholder group) and consensus (consensus preference within a MCDA stakeholder group) for our six stakeholder groups.

Future land-use option	*All participants*		*Big Farms*			*Conservationists*			*Counties*			*Forest Users*			*Pastoralists*			*Smallholders*		
	Individual		Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus	Individual		Consensus
	N=51		n=7			n=14			n=5			n=6			n=7			n=12		
	M	SE	M	SE		M	SE		M	SE		M	SE		M	SE		M	SE	
Business As Usual	17.03	0.57	14.62	1.12	17.66	15.77	0.952	13.15	17.68	1.84	20.92	14.32	1.61	16.67	18.34	1.09	17.99	20.20	1.26	18.49
Farming Future	9.06	1.07	6.19	1.79	11.13	6.34	1.12	3.36	8.50	2.96	12.13	7.82	2.21	2.42	8.59	2.97	3.79	15.04	3.18	4.65
Forestry Future	37.23	1.94	40.03	5.94	57.36	40.15	2.96	15.48	46.40	3.38	29.19	28.32	4.63	28.49	38.68	6.61	43.99	31.97	4.48	22.97
Green Future	62.39	1.75	61.52	5.37	43.98	61.98	2.61	86.11	55.89	4.32	60.78	70.45	4.50	76.19	62.04	5.95	60.67	62.22	4.15	77.36
Blue Future	47.01	0.66	46.22	1.42	41.36	48.34	1.16	46.87	45.80	3.01	48.62	49.41	2.38	54.10	46.00	1.20	47.52	45.77	1.51	58.88

Kenya's Central Highlands requires meaningful engagement with the local communities living within the target landscapes, particularly because delivering restoration successfully will be complex in countries transitioning through economic development. Moreover, the study region is experiencing more variable and intense rainfall due to climate change (Schmocker et al., 2016), so environmental interventions to promote water infiltration and slow river discharge (Notter et al., 2007) should be viewed favourably. Nevertheless, in contrast, Kenya's lowlands are experiencing more pronounced and frequent droughts (Collier et al., 2008), meaning national priorities for agriculture, forestry and other land-uses will inevitably shift. This reinforces the need to integrate conservation and restoration within wider land-use planning that scales from catchment-level through to national-level (Chazdon et al., 2021). More widely, our findings also mirror those from other studies on maintaining ecosystem integrity in Afromontane systems, with many comparable potential opportunities and challenges identified (e.g. Mengist et al., 2020, Downing et al., 2023). For example, Malek et al. (2019) also found that stakeholders highly value diverse provisioning, regulating and maintenance services. Therefore, multi-stakeholder, ecosystem service-based decision-making must be accessible, enabling polycentric governance to incorporate environmental and social heterogeneity and address power imbalances effectively (Chazdon et al., 2021; Schweizer et al., 2021; Xu and Peng, 2022).

4. Conclusion

Governments, industries and civil society recognise the scale of the climate and wider ecological crises, but now must agree on how to act (Bhola et al., 2021; Convention on Biological Diversity, 2020; Milner-Gulland et al., 2021). Success will depend in part on effective stakeholder engagement, but participation should be considered as early as possible and represent relevant stakeholders systematically (Carrick et al., 2022). Here, we demonstrate that structured decision-making can engage a diversity of stakeholders, including local communities, revealing a general preference for landscapes where biodiversity is conserved and restored. This is obviously only the first step, as implementing restoration actions in priority areas involves accounting for a wide range of environmental, economic and social conditions (Hemming et al., 2022). However, employing structured decision-making effectively allows stakeholders to evaluate future land-use options from a landscape perspective (Chazdon et al., 2021), providing a transparent and defensible way to build local support for restoration, as well as achieving the 2050 goal of living in harmony with nature (Convention on Biological Diversity, 2020).

CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

Acknowledgements

GMEG was funded by a University of Kent Vice Chancellor's Research Scholarship. We thank S. Black, L. Maamai, H. Matimele, D. Seaman and M. Lo for providing feedback on the pilot data collection process.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2024.107364.

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