CONSERVATION INTERNATIONAL

Ecosystem-Based Adaptation and Mitigation in Botswana's Communal Rangelands

Annex 11: Monitoring and Evaluation Plan

M&E Plan Supplementary Materials:

Please also see the following Funding Proposal documents for more detail on Project M&E methodologies:

- Appendix 11.1 – attached separately
  - Protocol for long-term monitoring of Rangeland condition.

- Annex 2 (Feasibility Study), Section 3, Appendices 3.3, 3.4, and 3.5:
  - Methodologies for calculating emissions reductions from both livestock and ecosystems

- Annex 2 (Feasibility Study), Section 4, Appendix 4.9
  - Adaptation beneficiary calculation spreadsheet

Table 11.1 Monitoring Plan[1]:

Monitoring				
Data/Source	Collection Tool	Frequency	Indicator	Indicative Budget[2]
Outcome M9: Improved management of land or forest areas contributing to emissions reductions				
Government: Botswana GHG Inventory in UNFCCC National Communications; Stats Botswana Annual Agricultural Survey Report. **Project:** Mid-term and Final Evaluation Reports to have a section dedicated to Mitigation Targets based on application of	*Government data/records*	*Mid-term (After year 4)* *Final (After year 8)*	**M4.1 / Output 2.2 Tonnes of carbon dioxide equivalent reduced or avoided via forest and land use change** **Mid-term:** 797,430 tCO_2e emissions reduction from baseline **Final:** 4,703,498 tCO_2e emissions reduction from baseline	*$350,000**

[1] Please note that many Project outputs will contribute to multiple Outcomes - the information presented in this table is approximated based on the primary Outcome for each Output. The M&E Plan will be further develop at the project inception phase involving all relevant stakeholders.
[2] Indicative budget is for GCF Grant finance only. Please note that government co-finance will provide **~19M USD** for the salaries of Graduate Monitors, who will contribute to Project M&E across all project Activities.

Baseline Calculation Model. See Section 3 in Annex 2 Feasibility Assessment.				
Government: Govt Rangeland Stewardship Information Portal GIS Data coverage of Rangeland Stewardship Agreement Maps **Project:** Mid-term and Final Evaluation Reports to have a section dedicated to hectares restored and hectares under improved management using data consolidated by Ecorangers in new Rangeland Stewardship Information Portal. Impact reports to compare key ecosystem service indicators to control sites. See Section 5b in Annex 2 Feasibility Assessment	*GIS data*	*Annual* *Mid-term (After year 4)* *Final (After year 8)*	**M9.1 / Output 2.2 Hectares of land or forests under improved and effective management that contributes to CO2 emission reductions** **Annual:** Measurement of total hectares under various stages of RSA development and enforcement. **Mid-term:** 1 million hectares under improved management **Final:** 4.6 million hectares under improved management	*$550,000** **M4.1, M9.1, and associated Outputs will contribute to mitigation targets, which represent ~30% of total GCF resources.* *Total GCF-Funded M&E = ~$3.4M*
Outcome A7: *Strengthened adaptive capacity and reduced exposure to climate risks*				
Government: Stats Botswana Annual Agricultural Survey Report; Drought Impact Reports; Rangeland Stewardship Information Portal **Project:** Mid-term and Final Evaluation Reports to have a section dedicated to improvement of adaptative capacities (ecosystem, livestock, or income), using data consolidated by Ecorangers in new Rangeland Stewardship Information Portal See Figure 11.1 below and Section 5b in Annex 2 Feasibility Assessment	*Government data/records*	*Annual* *Mid-term (After year 4)* *Final (After year 8)*	**A1.1 Percentage of uptake of resilience practices by vulnerable populations and businesses (Outputs 1.1, 2.2)** **Mid-term:** **1.1:** 50% correct responses on post-training assessments (measurement of successful training uptake) 25% of farming population in Project areas have been engaged to design Stewardship Agreements (44,100 individuals) Female farmers represent at least 30% of signatories of Rangeland Stewardship agreements **2.2:** Use of fund supported skills, Ecorangers and mobile livestock support	*$400,000*

			infrastructure results in improvement across 30% of the target Village Grazing Areas in the following key mitigation and ecosystem resilience indicators: number of hectares under active restoration (TBD based on site assessments) At least 20% improvement in ecosystem resilience indicators across 30% of the target Village Grazing Areas At least 20% decrease in unnatural livestock mortality across all implementing Village Grazing Areas (Phase 1) **Final:** **1.1:** 90% correct responses on post-training assessments (measurement of successful training uptake) 80% of farming population in Project areas have been engaged to design Stewardship Agreements (176,500 beneficiaries) Female farmers represent 40% of signatories of Rangeland Stewardship agreements **2.2:** Use of fund supported skills, Ecorangers and mobile livestock support infrastructure results in improvement across 80% of the target Village Grazing Areas in the following key mitigation and ecosystem resilience indicators: X number of hectares under active restoration (TBD based on site assessments)	

			At least 50% improvement in ecosystem resilience indicators across 80% of the target Village Grazing Areas At least 50% decrease in unnatural livestock mortality across all implementing Village Grazing Areas (Phase 1, 2, 3)	
Government: Rangeland Stewardship Information Portal, Ministry of Agriculture Ipelegeng Employment Records. Stats Botswana Household Survey (data on income resilience) Impact evaluations to assess key household resilience statistics from project sites to non-project sites); **Project:** Mid-term and Final Evaluation Reports to have a section dedicated to assessment of number, gender, and types of beneficiaries with increased climate-resilient livelihoods, including information from project value-chain participation reports including securing purchase agreements for RSA compliant farmers, compiled by the Project Enterprise Manager. Impact evaluations to assess key household resilience statistics from project sites vs non-project sites. Private Sector and BAITS inputs on sales records per RSA; Impact evaluation analysis will compare with	*Government data/records*	*Annual* *Mid-term (After year 4)* *Final (After year 8)*	**A1.2 Numbers of males and females benefitting from diversified, climate resilient livelihood options (increased household and business income from climate-resilient livestock value-chains, regional economies stable despite climate shocks)[3] (Outputs 2.1, 3.1)** **Mid-term:** At least 60,000 individuals **Final:** At least 247,000 individuals	*$900,000*

[3] Beneficiaries will be counted according to two types of benefits received: i) Livestock production beneficiaries (i.e. farmers involved in communal livestock production) and economic impact beneficiaries (i.e. other connected workers along the value chains, such as traders, vendors).

Stats Botswana Household Survey Data for non-target areas.				
Government: Rangeland Stewardship Information Portal, Ministry of Agriculture Ipelegeng Employment Records. Stats Botswana Household Survey (Impact evaluations to assess key household resilience statistics from project sites to non-project sites) **Project:** Annual, Mid-term and Final Evaluation Reports to have a section dedicated to Rangeland Stewardship Information Portal Labour Statistics. Impact evaluation post-doc analysis of data and focus group discussions to compare Project Job Creation to other Job Creation investments on improvement in resilience indicators. See Section 5a&b in Annex 2 Feasibility Assessment	*Government data/records*	*Annual from Year 2* *Mid-term (After year 4)* *Final (After year 8)*	**Output 2.1 Total # of men and women with new livelihood strategies (skills and employment) related to climate resilient land and livestock management** **Mid-term:** 2000 individuals (men: 800; women: 1200) **Final:** 6000 individuals (men: 2400; women: 3600)	*$400,000*
Outcome A5: Strengthened institutional and regulatory systems for climate-responsive planning and development				
Project: Annual, Mid-term and Final Evaluation Reports to have a section dedicated to Rangeland Stewardship Information Portal User Statistics See Section 5a in Annex 2 Feasibility Assessment	*Document review*	*Phase II Self-Assessment (After year 5)* *Final (After year 8)*	**Output 1.4 New rangeland monitoring system is operationalized , embedded and utilized in market, carbon monitoring and policy systems** **Mid-term:** Climate responsive RSAs are designed and deployed using data from RSIP by 50% of project communities **Final:** Climate responsive RSAs are designed and deployed using data from RSIP by 90% of project communities	*$150,000*

Project: Mid-term and Final Evaluation Reports to have a section dedicated to analysis of lesson uptake into key policy platforms and programme budgets (incl. leveraged funding, status of CBT, regional trade barriers, status of BMC, and the overall policy environment) Section 5a in Annex 2 Feasibility Assessment	*Document review*	*Mid-term (After year 4)* *Final (After year 8)*	**Output 1.5 Key policies reflect project lessons learned** **Mid-term:** Project objectives and lessons represented in the NDC, NDP and GDSA Review documents **Final:** Plan for scaling Project to all of Botswana tabled to National Development Plan	*$75,000*
Government: Govt Rangeland Stewardship Information Portal; LUCIS Database Review Reports **Project**: Annual, Mid-term and Final Evaluation Reports to have a section dedicated to number, gender that participated in training about climate resilience practice and in the design of Rangeland Stewardship Agreement as per outreach assessment scorecard. See Section 5a in Annex 2 Feasibility Assessment	*Document review*	*Annual* *Mid-term (After year 4)* *Final (After year 8)*	**Output 1.1 New gender equitable structures and systems for climate responsive planning and implementation by communal populations are operationalised** **Mid-term:** 50% correct responses on post-training assessments (measurement of successful training uptake) 25% of farming population in Project areas have been engaged to design Stewardship Agreements (44,100 individuals) Female farmers represent at least 30% of signatories of Rangeland Stewardship agreements	*$70,000*

			Final: 90% correct responses on post-training assessments (measurement of successful training uptake) 80% of farming population in Project areas have been engaged to design Stewardship Agreements (176,500 beneficiaries) Female farmers represent 40% of signatories of Rangeland Stewardship agreements	
Government: National Development Plan Annual and Mid-term Reviews **Project:** AHEAD Scorecard on CBT; RSA Participating and Non-participating Farmer Questionnaire. See Section 5a in Annex 2 Feasibility Assessment	*Survey/questionnaire*	*Mid-term (After year 4)* *Final (After year 8)*	**Output 1.2 New job creation programme and veterinary approach for climate responsiveness are adopted by national departments.** **Mid-term:** 30% improvement in targeting needs of farmers through inclusion of climate change risks and strategies in national job-creation and animal health disease prevention for climate resilience **Final:** 80% improvement targeting needs of farmers through inclusion of climate change risks and strategies in national job-creation and animal health disease prevention across all sub-regions	*$70,000*
Project: Specific Behaviour Change Impact Assessment Report; Mid-term and Final Evaluation Reports to have a section dedicated to systems for climate responsive planning and their implementation, based on Rangeland Stewardship Information Portal, Ministry of Agriculture Ipelegeng and Dept of Vet Services Dashboards		*Annual from Year 2* *Mid-term (After year 4)* *Final (After year 8)*	**Output 3.2.:** Level of climate-resilient awareness of selected financiers and value-chain players and adoption of carbon-optimisation practices and technologies **Mid-term:** 30% improvement in awareness and operations (behaviour & technology) changes **Final:** 80% improvement in awareness and operations (behaviour & technology) changes	*$70,000*

Table 11.2 Evaluation Plan:

Evaluation			
Type	Timing	Independent/Self-evaluation	Indicative Budget[4]
Process	Farmer Facilitation Team Training Effectiveness	Self-Assessment	**$45,000**
Formative	Phase I Demonstration Phase Review (After 2 years)	Self-Assessment	**$20,000**
Formative	Phase II Replication Phase Review (After 5 years)	Self-Assessment	**$30,000**
Formative	Phase I Curriculum Review (After Year 2)	Independent	**$37,000**
Formative	Phase II Curriculum review and Qualification Application (Year 5)	Independent	**$37,000**
Process	Mid-term Review (After 5 years)	Independent	**$47,000**
Impact	Phase I & II Review (After 5 years)	Self-Assessment	**$150,000**
Impact	Final (After 8 years)	Self-Assessment	**$150,000**
Summative	Final (After 8 years)	Independent	**$47,000**

[4] Indicative budget figures included in 11.2 are part of the total M&E budget presented in table 11.1

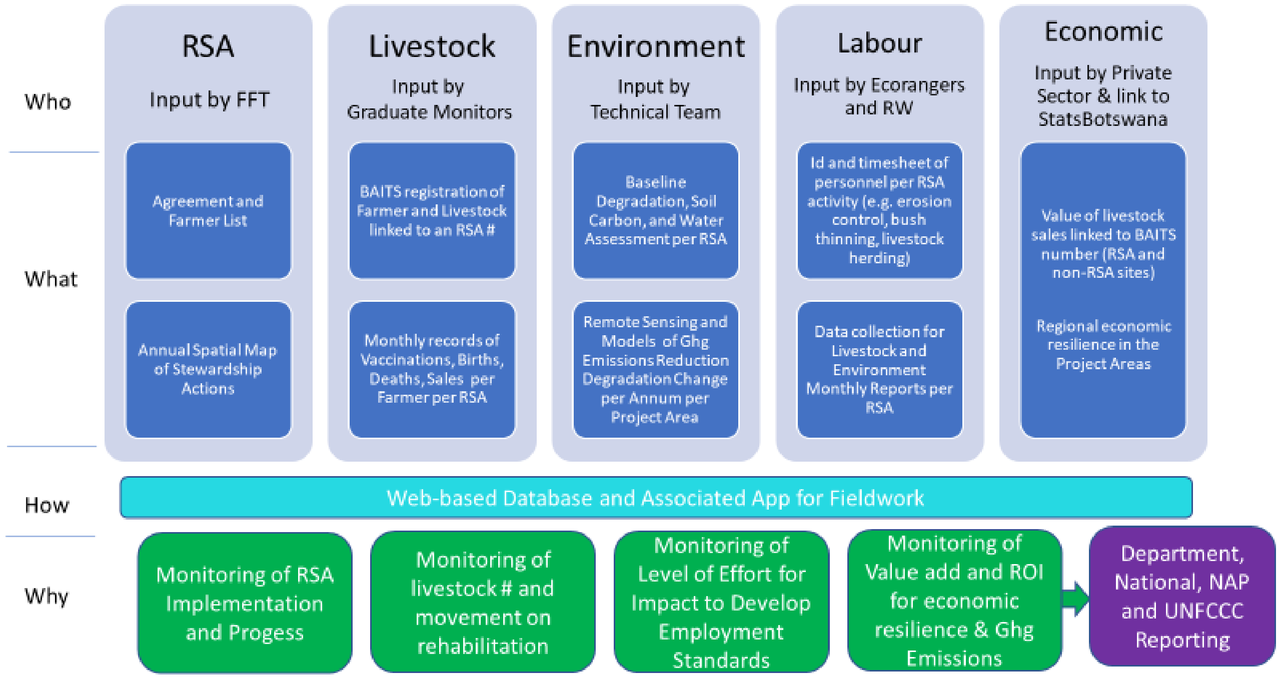

Figure 11.1 Depiction of Rangeland Stewardship Information Portal as relevant to the M&E Plan

11.3 Development of the full M&E Plan

The full M&E Plan will be developed during the project inception phase (within the first 6 months of project implementation). The Plan will be developed with the new project M&E staff in collaboration with M&E staff from the CI support team, government agencies, and local partners. The full M&E plan will include detailed information on the roles and responsibilities for data collection and management, project components' impact chains, information flows and reporting systems, finalized indicators and means of verifications, monitoring protocols and tools, implementation plans and schedules, alignments and collaborations with existing national M&E systems (e.g. stats Botswana). The M&E plan will also include participatory methods for data collection and learning (see section 11.3.1) and an impact evaluation plan (section 11.4).

11.3.1 Restoration, Grazing, and Engagement Monitoring and Peer Learning

Within a cluster of Village Development Committees, WhatsApp groups will be established with a system of recording a photo, location, and short description developments or findings in the field. At least two graduate monitors per cluster will be tasked with consolidating the information into a simple excel spreadsheet that is easily searchable. Monthly reports will be sent to managers for further consolidation and analysis of any trends detected and for uploading into the Rangeland Stewardship Information Portal. Temperature and precipitation data will be gathered by Ecorangers and/or Graduate Monitors and uploaded into the Portal for further access and analysis by the MET on climatic trends and recommended responses. In addition, all stakeholders will be encouraged to contribute to the Village Grazing Area Rangeland Stewardship and Climate-resilient Livestock Production Community Diaries as participatory documentation of Project implementation for 104 communal grazing areas. The diaries will include before/after photos, experiences and lessons learned, and will be held by the VDC as a scrapbook or set of scrapbooks. Graduate Monitors will be provided with tools and training to start VDC level websites, so documentation is electronic as well as physical. This system is currently being tested in one Herding for Health landscape and is resulting in extensive co-benefits including better delivery via peer-learning, expansion of biodiversity knowledge within different sites, more rapid course correction by management, and better identification of skills in field staff. The evidence base has also been used to develop reports for policy recommendations that are grounded in field experience.

An additional Whatsapp group will be set up across all Farmer Facilitator Team members in the project with at least two graduate monitors per area being tasked to consolidate this information on village-level engagements for sending to the Project Area Managers and providing relevant information into the Rangeland Stewardship Information Portal; as well as providing documentation for Project case studies and best practices for future use by Herding for Health partners.

11.3.2 Measurement of emissions reductions

To measure the impacts of grazing and restoration management on emissions reduction, the following indicators will be gathered:

- "**Grazing intensity", informed by**:
  - **Biomass** (kg/ha) from disc pasture meter, remote sensing models and satellite-based products such as FAO WaPOR (presented in Annex 2 Section 3 pg. 19–25)
  - **Basal cover** from long-term rangeland condition monitoring (Appendix 11.1), remote sensing models and satellite-based products such as fractional bare ground.

- **Lignin and cellulose content, informed by**
  - **Grass species composition** from long-term rangeland condition monitoring (Appendix 11.1) for Project sites. Reference sites will also be measured for mid-term and final impact evaluation reports. Remote sensing models will also be utilized (e.g., Ramoelo et al. 2015)

- **Livestock numbers and weight**
  - For Project sites, livestock numbers will be gathered and updated monthly by Ecorangers and captured in the Rangeland Stewardship Information Portal with trend analysis by the Graduate Monitors and referenced against the Stats Botswana Annual Agricultural Survey Report. Average weight trends per village herd will be integrated into reports on wet and dry season vaccinations. This will be compared to reference site estimates from MoA veterinary records as without the RSA it will be impossible to get similar detail on livestock where farmers are not participating in active communal management (e.g. BAU/status quo).

- **Feed digestibility**
  - **Grass species composition** (as described above)
  - **Biomass** (as described above)
  - **Manure evaluation augmented by fecal nitrogen analysis.** Ecorangers to undertake sampling of dung viscosity as an indicator for feed digestibility that can then be translated into an estimate for emissions reductions. The exact methodology may vary per Area and season due to climate/habitat factors. This information will be reviewed and augmented with chemical analyses carried out by the MoA Nutrition specialist.

- **Activity coefficient**
  - Qualitative categorization of the average energy expended (distance walked per day) to acquire enough grazing material. This can be monitored based on the number of livestock within controlled herds as captured in the Rangeland Stewardship Information Portal with input from the Graduate Monitors.

- **Methane conversion factor**
  - This is based on feed digestibility (described above), herd structure (number and age of males/females), and livestock health indicators (vaccinations, fertility rate, death rate) that can be monitored based on the Rangeland Stewardship Information Portal with input from the Graduate Monitors.

CI will use these indicators as model parameters for the SNAP biogeochemical model (Ritchie 2014) to estimate the emissions reductions (ER) from the project's livestock and rangeland management activities. This modelled approach quantifies the ER in a manner consistent with VCS VM0032 (https://verra.org/methodology/vm0032-methodology-for-the-adoption-of-sustainable-grasslands-through-adjustment-of-fire-and-grazing-v1-0/).

The above-ground vegetation dynamics will be monitored for the purposes of evaluating the rangeland condition to inform management decisions, implementation success and to evaluate project impacts. Herbaceous biomass production will be measured using a disc pasture meter and changes to woody cover and vegetation structure will be measured using fixed-point wheel spoke repeat photographs, line-point intercept transects and remote sensing products. All the measurements will be captured in the Rangeland

Stewardship Information Portal with trend analyses conducted by the Graduate Monitors. These data are not intended to be used to claim any ER benefits from changes in the above-ground carbon stocks as a result of the conservative de minimis assumption.

11.3.3 Progress on Enhanced Income-based Adaptive Capacity and Sustainability

A Project Village Grazing Area Self-Assessment Progress Dashboard will be created for annual performance measurement on progress towards sustained adaptive capacity. Ratings will be as follows:

- 0 for no agreement;
- 1 for Rangeland stewardship agreement development complete but not yet signed or endorsed by Land Board;
- 2 for conservation agreement adopted, signed, and implementation in practice;
- 3 for Rangeland stewardship agreement adopted, signed, and implementation in practice and Land Board supporting enforcement;
- 4 for Rangeland stewardship agreement adopted and stakeholders progress report identifies the year as a "Project Success" according to the criteria established for climate vulnerability reduction and offtake arrangements in that cluster based on the viability determined in Activity 3.1.1b;
- 5 for Rangeland stewardship agreement integrated and fully sustained through private sector supplier contract and community and Land Board governance structures

At all stages the RSA and offtake arrangements will be assessed by CI's Monitoring Team, including the Gender Officer, to ensure equitable representation of interests of male, female, indigenous population participation and differences between cattle owners and small stock owners.

Private sector engagement and commitment to continued offtake arrangements with RSA compliant farmers will be determined through an analysis of sales data and structured interviews conducted by the graduate monitors within each cluster and with national players by the Enterprise Manager for annual monitoring of progress towards sustainability of the agreements. As a RSA environmental condition is restored, and the Herding for Health model is sustained through private sector markets / offtake agreements and community governance structures, a final rating of 5 will be given to the VGA. The Project target is that 80% of all 104 VGAs reach a level 5 rating by Year 9.

11.4 Project Impact Evaluation – Summary Description:

Complementary to the overall Project Monitoring and Evaluation Plan, the Project will also undertake an Impact Evaluation (IE) to better determine and measure the project-attributable impacts of interventions. The IE will be conducted with the support of CI's Moore Center for Science and will use the same data sources (project and government) used in the overall Project M&E system.

Rigorous impact evaluation (IE) methods help to assess the causal effect on desired outcomes from interventions by controlling for the non-random allocation of intervention activities. The IE design will identify a counterfactual or control to estimate the mean difference between the outcome with intervention and the outcome without it through a matching procedure. A counterfactual enables a comparison of the condition with what would have occurred in the absence of the intervention (Ferraro, 2009). A well-designed IE will capture the treatment effect on the outcome as opposed to overestimating positive or negative effects (Imbens & Wooldridge, 2009; Khandker, Koolwal, & Samad, 2010). Conducting an IE is important to generate unbiased evidence for project managers, project beneficiaries, and donors to measure effectiveness of what works, what does not, and why. This is done by testing whether the causal changes are connected to the intervention pathways and reveals the ways the project is leading to targeted outcomes, i.e., reducing rangeland ecosystems degradation and national GHG emissions; increasing ecosystem health, increased socioeconomic well-being of beneficiaries, and improved climate resilience through improved livestock management practices.

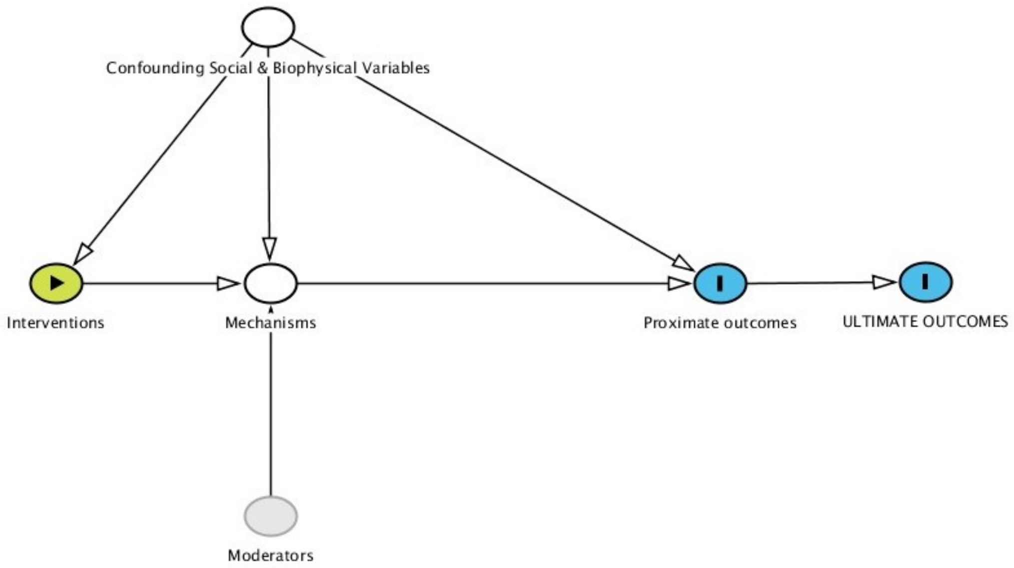

Figure. 11.2 Simplified impact evaluation (IE) determination of causal pathways.

The figure above depicts how the interventions or project activities (green oval) affect the proximate outcomes which lead to ultimate high-level outcomes (ovals in blue). The confounding variables (white ovals) are the elements of the coupled social-ecological systems the IE need to control for. The directionality of the causal pathway is indicated by arrows. The pathway is moderated by regional level or local level variables represented by the gray oval; the moderators (e.g., participation in community activities) affect the magnitude of the impact of the interventions or the mechanism. The causal relationship confirms assumptions in the theory of change to be tested through the impact evaluation design.

The IE will utilize advanced methods in remote sensing, spatial econometrics, and social science to explore the causal effects of the project activities through sequential steps. The IE design will use the Project defined theory of change and pathways to identify appropriate models, then develop a sampling strategy for treated and counterfactual units, perform analysis, and communicate results to inform the adaptive management of the Project over the course of implementation.

As part of the IE, CI will address the potential project's positive and negative spillovers and interference (i.e., effects in and outside targeted populations and borders) to measure reduce or increase net impacts (VanderWeele, 2015). CI will do this by developing and monitoring indicators directly associated to the channels and mechanisms by which spillovers operate. As suggested by Pfaff and Robalino (2017) some of these channels are input reallocation; market prices; learning; nonpecuniary motivations; and ecological-physical links. This will require identifying the mechanistic relationship through which the project interventions affect the outcome and explaining the process of change from an initial stage leading to an intermediate or final stage (the outcome). For example, in the presence of leakage of slippage a farmer who face restriction on resource use can lead to continue unsustainable grazing and land clearing in other land parcels (input reallocation), leading to increases in measurement of land degradation above-baseline. By not considering this spillover effect the program may show no impact or negative impact. Similar spillovers arise from cash transfers in the form of incentive payments that increase the capacity of a participant in the project to buy goods and use those to work in areas outside the program potentially leading to no project effect at the landscape level. Our proposed impact evaluation plan will assess the mechanisms whereby causal effects arise when interference and spillover effects are present.

The IE design and execution plan will be developed during the first six months of Project implementation during the training and staffing phase. The IE design will include data collection through different instruments including GIS datasets, ground-truthing of impacts, interviews with beneficiaries, census / household income data, livestock data from government and the Rangeland Information Portal, and governance information from Village Development Committees. The data analysis will consist of comparing results from baseline measurements and control areas to target areas and populations that receive Project interventions. A preliminary selection of indicators to assess outcomes include M4.1, M9.1, A1.1, and A5.1 as described above, but final selection of indicators to be measured through the IE will take place during the development of the full IE methodology. For example, rather than monitoring water deficit indices — such as SPEI — which are based on the meteorological water balance that is not expected to be significantly impacted by the project, the rangeland condition will be monitored to determine the project impact. While it is likely that improvements in aquifer recharge rates and soil water contents may improve at some sites where restoration activities have been implemented, particularly the clearing of invasive alien plants, these benefits would be highly site- and context-specific. CI, therefore, makes no claims about reducing overall water deficits through this project.

The IE Plan will be designed to be sensitive to the need for adaptive management of the project which will benefit from preliminary results from M&E and IE analyses. The selection of indicators and outputs will be informed by the project managers and relevant stakeholders at all levels. The final results of the IE will be communicated to beneficiaries and decisionmakers through presentations, workshops, policy briefs, and at least two peer reviewed publications.

Impact Evaluation Key References

Ferraro, P. J. (2009). Counterfactual thinking and impact evaluation in environmental policy. In M. Birnbaum & P. Mickwitz (Eds.), *Environmental program and policy evaluation: Addressing methodological challenges* (Vol. 2009, pp. 75-84). San Francisco, California, USA: Wiley Subscription Services, Inc.

Imbens, G. W., & Wooldridge, J. M. (2009). Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature, 47*(1), 5-86. doi:doi: 10.1257/jel.47.1.5

Khandker, S. R., Koolwal, G. B., & Samad, H. A. (2010). *Handbook on impact evaluation: quantitative methods and practices*: World Bank Publications.

Pfaff, A., & Robalino, J. (2017). Spillovers from conservation programs. *Annual Review of Resource Economics, 9*, 299-315.

VanderWeele, T. (2015). *Explanation in causal inference: methods for mediation and interaction*. Oxford: Oxford Univ. Pr.

Ecosystem-Based Adaptation and Mitigation in Botswana's Communal Rangelands

Annex 11 Appendix A: Protocols for long-term monitoring of rangeland condition

PROTOCOLs FOR LONG-TERM MONITORING of RANGELAND CONDITION

PHOTO POINTS, LINE-POINT INTERCEPT and BIOMASS PRODUCTION

Introduction

We aim to conduct rapid rangeland condition assessments that are suitable for long-term monitoring post various interventions concerning good rangeland practice and also to inform municipal climate vulnerability assessments. We have a choice of monitoring different types of soil cover: **basal cover, folia cover** and **canopy cover**. Basal cover varies less with rainfall than foliar cover, both within and among years, making it more suitable for monitoring long-term vegetation trends[1]. **Basal cover measurement is most useful in areas dominated by perennial grasses**, which have relatively large basal areas (crowns), e.g. in the Grasslands Biome. The use of both basal and foliar, or just foliar cover is more suitable for the Succulent Karoo. Canopy cover will be assessed where woody elements over 1.5 m dominate. Specifically we aim to:

a) Assess *site productivity* or *grazing value* of a test site relative to *benchmark site*. The benchmark is based on the most productive rangeland for the vegetation type concerned, either from published values (e.g. in Bioresource Groups of KwaZulu-Natal) or from available data.
b) Assess *site biodiversity at selected sites* relative to *benchmark site*. The benchmark is based on the most biodiverse mature rangeland site for the vegetation type concerned from available data.

We will do this using fixed **photo points** to provide visual qualitative data, **line-point intercept** data to provide quantitative soil cover data. Since vegetation change post any intervention will likely be measurable in the range of 3 to 5 years, and possible not measurable in terms of change species composition, measuring **biomass production** will also be useful.

Photo points are a quick, low cost way to assess rangelands from year to year. Panorama photos are qualitative but very helpful for seeing how vegetation changes if you take them in the same season. Ground cover photos provide repeatable quantitative data on plant cover, density and frequency. If time and resources are limiting, only photo points can be taken at a site. Together with the line point intercept method, photo points are very useful as long as they are accompanied by site history. The **Line-point intercept method**[2] is recognized internationally as the only accurate method for assessing condition and biodiversity of Grassland, Shrubland and Savannah rangelands. It is a rapid, accurate method for *quantifying soil cover*, including vegetation but also litter, rocks and biotic crusts *along a line at regular intervals or points*. Pins or optical sighting devices can be used to locate the points, and assessment can be in a single layer (e.g. just grasses and forbs) or multiple layers (e.g. to assess woody elements as well). *Here we use pins to locate points at 1m intervals and assess cover in a single layer, unless significant woody elements occur, where multiple layers are used.* To measure small changes over time at least 1000 points are recommended[3,4,5,6,7,8] but for quick assessments over large areas **200 points** is acceptable[1] and routinely used in South Africa.

The rangelands **biomass production** using a Pasture Disc Meter (DPM) is useful to detect changes in plant vigour and where species composition does not change, e.g. under stable management or slight management change. At least 100 points should be measured per site The DPM is also useful for determining fuel loads when managing veld burning.

Method

Equipment list for photo points

- Clipboards, Photo Point ID white board (App. 1), field note book, pens
- Mobile phone and contact numbers
- Metal rebar stakes and spray-paint
- SLR Camera with 18 mm lens, 15 megapixel memory or more, able to shoot RAW format
- Camera tripod (set to 1.5m) or hollow plumbing pipe
- GPS and spare batteries

Equipment list for biomass production

- Disc pasture meter

Equipment list for line-point intercept

- Measuring tape (50 m)
- Two steel pins for anchoring tape
- A pointer (straight piece of wire at least 75 cm long and less than 1 mm in diameter)
- Clipboard, Line-Point Intercept Data Form (App. 2)
- Brown paper packets for plant samples
- Secateurs
- Field guide books
- Auger (optional to check soil)

General

1. **Site selection**. Choose sites according to i) aims of the study, ii) scope and iii) resources. For example, in the local Matatiele Municipal area we stratified sampling according to a raster of 9 x 8 km squares over the area, and randomly assigned sampling points in natural veld. Once on a representative area of your site, exact transect placement is semi-randomly, i.e. choose random areas and then check that they are ecologically homogeneous: area with continuous uniform patterns of slope, aspect, soil type, rockiness and vegetation[9]. Also avoid disturbed or obviously different areas (within 50m of a road, excavations, heavy foot/hoof traffic area).
2. Ideally the **same evaluator/s** will assess a project, site or farm. This is not always possible, so it is important to follow this protocol very closely.
3. For reasons of safety and convenience, work in **pairs** (one observer, one recorder) or **threes** (one observer, one recorder, one 'runner' OR one person to do photo points and biomass production and two people to do line-point intercepts).
4. Obtain **site history** from the landowner, and ideally have them come along, at least initially.

Fig. 1a. Panorama photo points are taken from a fixed height of 1.5 m and GPS point, with a permanent stake and photo point ID board at the bottom centre of the photo. Photos can be taken for each compass direction or transect.

Fig. 1b. Ground cover photo points are taken from a fixed height of 1.5 m and GPS point, with a photo point ID board at the bottom left of the photo. Photos can be taken for each compass direction or transect.

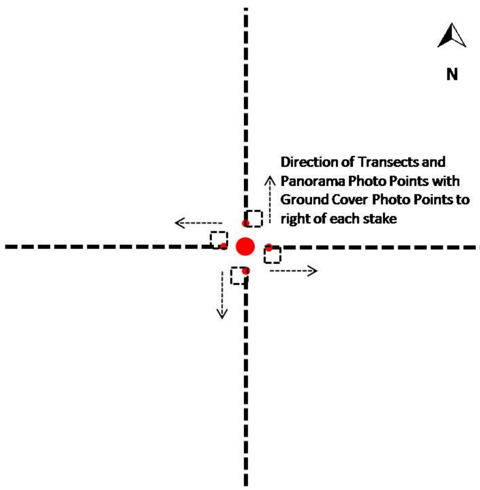

Fig. 2. 'Wheel spoke' layout for photo points and transects

Photo points & GPS

Set the camera to take RAW format (or RAW+JPEG) and ISO to 100. Read the camera manual to familiarize yourself with the camera before setting out. Take care to keep your feet, other people's feet and their shadow's out of the photo:

1. **Stake a central GPS point** and note the location on the **Photo Point Identification Board** (Appendix 1) and the **Line-Point Intercept & Biomass** data form (Appendix 2)**.** The GPS waypoint should be given in **decimal degrees**.
2. **Use the central stake as the start of the transects** (4 x 50 m) in each compass direction.
3. Fill in site details and hang the **Photo Point Identification Board** (Appendix 1) on the stake.
4. Take **Panorama Photo Points** from a central GPS point in each compass heading so that the base of the stake is at the centre bottom of the photo (Fig. 1a), the camera lens is set to 18 mm and is at 1.5 m, and the two stakes are aligned in the middle of the photo. (Use a tripod set to 1.5 m or a 1.5-m long plastic plumbing pipe placed over a central stake). Ideally leave the central stake there.
5. Take **Ground Cover Photo Points** for each heading from a height of 1.5 m downwards. Place the Photo Point Identification Board (Appendix 1) to the right of the transect (Fig. 2a). Cover or density can be calculated by manually placing a set of points over the image and recording the cover type, or automatically using remote sensing software[10, 11].
6. Make any notes you can on management or climatic conditions

Biomass production

At least 100 points should be measured per site using the disc pasture meter, i.e. every 2 m along each 50 m x 4 transect. At each 2m-point allow the weighted disc to fall to the height of the standing biomass and note the cm on the **Biomass data form** (Appendix 2). The cm measurements are later converted to kg ha^{-1} using the calibration curve according to the standard used for grasslands and savannas in South Africa (**$y = -3019 + 2260\ (\sqrt{x})$**)[12] . A re-evaluation of the DPM method for research purposes found that if grass culms are >25 cm the correlation between cm and kg/ha is poor[13] and in that case the following formulas should be used:

For ≤ 25 cm: $kg\ ha^{-1} = [31.7176\ (0.3218^{1/x})\ x^{0.2834}]^2$ *($r = 0.979$; $r^2 = 0.951$; $P < 0.0005$)*

and

For >25 cm: $kg\ ha^{-1} = [17.3543\ (0.9893^{x})\ x^{0.5413}]^2$ *($r = 0.948$; $r^2 = 0.882$; $P < 0.0005$)*

where x is the mean DPM height in cm of a site.

Line-point intercept transects

1. **A layout of 4 x 50m transects of 50 points each (=200 points per site, one sampling unit)** with NS, SN, EW, and WE headings in a wheel spoke design is suggested (Fig. 2). However, use your own judgment regarding layout: Site geography or project aims may require a longer transect, e.g. **2 x 100 m** of 100 points each if you wish to include a transition from one vegetation type to another, or shorter, e.g. **8 x 25 m** of 25 points each within an 'island' of fragmented vegetation type.
2. If you have not yet staked and recorded the **central GPS waypoint** do so now (use **decimal degrees)**
3. Stake using metal posts, painted white, orange or red. Keep NS, EW, etc. bearings true along the transect. You can temporarily stake both ends of transect or even permanent stake both ends.
4. **Do not remove species** from the photo point or transect. Find the same species outside the plot. If you remove species from the plot, it will affect your assessment results on that day as well as in the future.

a. **Transect:** Pull out the tape and anchor each end with a steel pin or around the stakes. The line should be taut and as close to the ground as possible (e.g. thread under shrubs using a steel pin as a needle).
b. Begin at the "0-m" end of the line. Always standing on the same side of the line (e.g. right), **drop the pointer to the ground at the first 1-m mark from a standard height**, e.g. hip height. Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the tape[i].
c. Once the pointer hits the ground, **record every plant species as basal cover**[ii] on the **Line-Point Intercept data form** (Appendix 3). Only record each species once for basal cover even if more than one hit for the same species occurs at that point. For successive hits at 2 m, 3 m etc., you can note species by making **'notches' in groups of five (~~||||~~).** Later, when processing data, the functional group, ecological group, grazing value and benchmarks can be filled in
d. Where the pin touches nothing, note it as **'none'**
e. If there a top canopy over 1.5 m high, i.e. you are under a shrub or in between the branches of a shrub or tree, project a line up to get a 'hit' and record plant species. Count 'tree elements' in increments of 1.5m.
f. **Circle dead species** on the form. (Remember that many desert plants or plants in the dry season only appear dead). If both live and dead canopy for the same species is hit on the same point, record the live canopy.
g. You can keep a database of the most common species and develop codes for them so that recording is rapid, e.g. *Themeda triandra* = TTRI).
h. If you know the genus but not the species, record a number for each new species of that genus, and note the functional group (App. 3) in the field (e.g. *Cymbopogon* species, *Cymbopogon* AG01). If you *cannot* identify the genus, only use the functional group and number (AG01), AND collect a sample of the unknown plant in a paper bag, labelled as in App. 3, for later pressing and identification.
i. As an option, if the pin does not intercept a plant base, record what the soil surface type is:
    a. **R** = Rock (> 5 mm or ~1/4 inch in diameter)
    b. **BR** = Bedrock
    c. **EL** = Embedded litter (removal would lead an indentation)
    d. **D** = Duff (litter on the soil surface)
    e. **BC** = Biotic crust on soil from moss, lichen, cyanobacteria..
    f. **S** = Soil that is visibly unprotected by any of the above

2. Calculate %bare ground and %basal cover according to the calculations on the form.
3. Calculate % of each plant species and calculate veld condition score and grazing value (Appendix 4) [14]
4. Calculate biodiversity as Shannon Index
5. As an option, calculate other interesting aspects, e.g. %dead plants, %biological crusts, etc.
6. **Note**: An abbreviated method for the Grasslands makes use of **key species** only[15]

Video: http://youtu.be/aJtuZRk_8n4

Line-point intercept method can measure:
1. PLANT SPECIES COMPOSITION
2. BASAL COVER
3. SOIL SURFACE TYPE AND COVER (optional)
4. FUNCTIONAL GROUPS
5. ECOLOGICAL GROUPS (Increaser, Decreasers)
6. GRAZING VALUE

Interpreting the Line-point intercept data

Increases in **basal cover** are correlated with increased resistance to degradation. Basal cover is less sensitive to seasonal and annual differences in precipitation and use than **foliar cover** but the latter is useful in Shrublands and Savanna while basal cover is more useful in Grasslands.

Increases in **bare ground** nearly always indicate a higher risk of runoff and erosion. Where species composition changes may be occurring, calculate basal and foliar cover for each major species.

Use these indicators together with the indicators of **biodiversity** and **grazing value** to assess the rangeland condition. Soil samples or analysis of encroaching vegetation may be needed to help determine whether observed erosion changes are due to loss of cover, changes in the vegetation's spatial distribution, or reduced soil stability. To get more information on biodiversity, rare species and encroachers use a Belt transect or a plot, e.g. Whitaker plot, to include species that transects may miss.

Typical effect on each attribute of an increase in the indicator value

Indicator	Soil/site stability	Hydrologic function	Biotic integrity
Foliar cover (%)	+	+	+
Basal cover (%)	+	+	+
Bare ground (%)	-	-	-
Grazing value	-	-	**n/a**

The Step-point intercept method
The *200 Step-point method* is often referred to in South Africa. This is very similar to the line-point intercept method. It is not accurate enough for long-term repeat measurements but is quite acceptable for quick assessments by landowners: A pointer is dropped in front of your boot at every step, instead of on points along a tape. Hits are recorded as for the standard method. This method is less accurate because it is difficult to walk a straight line with a true bearing, especially through shrubs. Using the toe of a boot instead of a dropped pin creates additional errors of bias, and if counting foliar cover, the boot often pushes plant canopies into interspaces, leading to overestimates of foliar cover.

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[i] A pair of lasers with a bubble level can be used instead of the pin. This tool is useful in savannas where plant layers may be above eye level.
[ii] Foliar cover can also be recorded if you record every plant species that touches the pointer above the ground. Foliar cover is useful in Shrublands and Savannas. In this case, intercepts are counted every time a different species touches the pointer. We will not record Foliar cover here.

APPENDIX 1

PHOTO POINT IDENTIFICATION BOARD

Use a re-usable white plastic board and black marker pen OR printed paper sheet on a clipboard

SITE:

TRANSECT #:

CENTRAL GPS:

DIRECTION:

VEG:

DATE:

APPENDIX 2

BIOMASS DATA FORM

Site: ______________________ Transect #: ______________________
Date: ______________________ Transect m: ______________________
GPS (00.00°): ______________________ Recorder: ______________________
Direction: ______________________ Observer: ______________________

Pnt.	BIOMASS (cm)	Pnt.	BIOMASS (cm)	Pnt.	BIOMASS (cm)	Pnt.	BIOMASS (cm)
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

APPENDIX 3

LINE-POINT INTERCEPT DATA FORM

Site: ______________________ Transect #: ______________________
Date: ______________________ Transect m: ______________________
GPS (00.00°): ______________________ Recorder: ______________________
Direction: ______________________ Observer: ______________________

#	PLANT SPECIES or NONE	#	PLANT SPECIES or NONE
1	*Themeda triandra*	19	None
2		20	
3		21	
4		22	
5		23	
6		24	
7		25	
8		26	
9		27	
10		28	
11		29	
12		30	
13		31	
14		32	
15		33	
16		34	
17		35	
18		36	

FUNCTIONAL GROUP CODES
AF# = annual forb; PF# = perennial forb; AG = annual graminoid/grass; PG# = perennial graminoid/grass; SH# = shrub; TR# = tree; GP# = geophytes; RT# = restiod or rush

APPENDIX 4

DATA PROCESSING

For each site and survey, record the following and/ or use 'Key Species' forms[16], [17]

No. PLANT COMPOSITION	SURVEY SITE			BENCHMARK
	Functional group	Ecological group	Grazing value	Grazing value
SUM				

CALCULATIONS[&]
%Bare ground= (NONE/2)*100 = x%
%Basal cover=(PLANTS/2)*100 = x%

[&]For 200 points. Multiply by 1 for 100 points per line. Multiply by 2 for 50 points.

GRAZING VALUES
These values will vary depending on the vegetation type.[10]

CALCULATIONS for GRAZING VALUE
Site sum/Benchmark sum *100

FUNCTIONAL GROUP CODES
AF# = annual forb
PF# = perennial forb
AG = annual graminoid/grass
PG# = perennial graminoid/grass
SH# = shrub
TR# = tree
GP# = geophytes
RT# = restiod or rush

ECOLOGICAL GROUPS

- Decreaser species. These species tend to die out (a) in veld which is too heavily grazed, (b) where grazing is extremely lenient and fire is excluded, or (c) where grazing is selective.
- Increaser I species. These species will replace Decreaser species where veld is too leniently grazed and fire is excluded.
- Increaser II species. These species replace Decreaser species where veld is overgrazed.
- Increaser III species. Unpalatable species that gain a competitive advantage and increase in abundance in overgrazed veld.

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