PROTOCOL

# Rangeland baseline master protocol

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Photo credit: Jason Sircely/ILRI

## PROTOCOL

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## Table of Contents

## A. Timeline for baseline roll-out

1. Identify monitoring locations (see Protocol RM1)

2. In each monitoring location, select the "monitoring area" and "trial area". Place LandPKS plots in the "monitoring area", and place LandPKS plots in the "trial area" that will be used to measure effects of restoration treatments ("Treatments" for restoration trials; plots in the "monitoring area" will serve as "Controls" for these trials) (see RM1).

3. For baseline biomass production in year-one, in the "monitoring area" fences are placed around subplots (see RM2) in each LandPKS plot, and all old leafy biomass (from previous seasons), for both herbaceous and woody plants, is removed from the subplots *(Note: Fencing is done only in the "monitoring area" LandPKS plots. The subplots are not fenced in the "trial area".).*

4. Take LandPKS measures at the first appropriate opportunity (see RM1). In most cases, this will be at the same time as subplot fencing, for logistical simplicity. Plant diversity and composition measures are best conducted at this time as well (see RM3). Soil samples can be taken now, or later at any time during year-one (see RM2). The first forage quality sample can be taken now, or when seasonal timing is appropriate (see RM2). Where relevant and seasonal timing is appropriate, baseline abundance of parasites and/or disease vectors are sampled (see RM4 for ticks).

5. Subplot biomass production is measured around the time of peak standing crop in year-one (see RM2), toward the end of a growing season. Subplot measures may also be conducted for soils (if soils were not sampled previously), and if seasonal timing is appropriate, for forage quality.

6. Start root ingrowth measures of belowground biomass production, where relevant and feasible (see RM5).

## B. Protocol RM1. LandPKS+

**Purpose**

LandPKS will be used to measure explicit spatial cover and height of vegetation (grass, forbs, shrubs, trees) cover of bare soil and rocks, land use, plant base density, and canopy and basal vegetation gaps, among other indicators. In addition to default LandPKS, information will be collected on the presence and cover of specific invasive, problematic, and/or highly beneficial species, photosynthetic soil crusts/lichen/algae, producer perceptions of land condition and its influences on livestock health, and grazing/browsing intensity.

LandPKS plots in a "monitoring area" provide information on rangeland condition and monitor its evolution over time, especially through linking these data to remote sensing layers. The LandPKS plots in the "trial area" measure effects of restoration treatments, as



compared to the “monitoring area” LandPKS plots which serve as “controls” in action research restoration trials.

**Core protocol—LandPKS**

LandPKS is a pre-eminent global rangeland monitoring tool (http://www.landpotential.org/). It is a simplified version of the US Department of Agriculture rangeland survey. The LandPKS app is downloaded directly to smartphones or tablets, and the LandPKS website provides extensive documentation and training videos.

Most measures in LandPKS are clear and unambiguous after a brief training of 2-5 days. However, some details may require clarification for precision monitoring. For example, the definitions of plant growth forms (annual grasses, perennial grasses, forbs, shrubs, trees) must be consistent in the baseline, and must also not change as monitoring progresses. For semi-woody plants commonly found in rangelands, each species must be considered to be either a “forb”, or a “shrub”, based on stem density (degree of woody lignification). These species groupings should be consistent across sites and time periods.

**Selection of monitoring locations and replication**

At minimum, 3 “general areas” are selected for monitoring (Figure LP1). There are a minimum of 3 “monitoring locations” (1 per general area), with 6 LandPKS plots in each monitoring location (Figure LP2). Where feasible, more monitoring locations are recommended. Increasing the number of LandPKS plots in a monitoring location (“pseudo-replication”) is not recommended (however, if more than one restoration treatment will be tested, an additional trial area can be added).

*STEP 1: List possible “general areas” for monitoring.* Communities direct selection of “general areas” for monitoring in communal rangelands. They must select a specific single pasture or grazing type, e.g. wet/growing season grazing areas, dry/dormant season grazing areas, all-season grazing areas, drought reserves, etc. Within this pasture or grazing type, the community is asked to indicate 3 general areas (at minimum), inside of which 3 monitoring locations will be placed (where feasible, more than 3 general areas are recommended).

Ask community representatives for a list of up to 10 areas in the rangeland that are (1) important for livestock feed, and (2) moderately degraded but can be rehabilitated. For each area, also note the pasture type—such as wet season area, dry season area, drought reserve, etc. For each area, also note the main type of degradation affecting it—such as major erosion/gullies, exotic invasions, bare soil, woody encroachment, and/or poor forage composition.



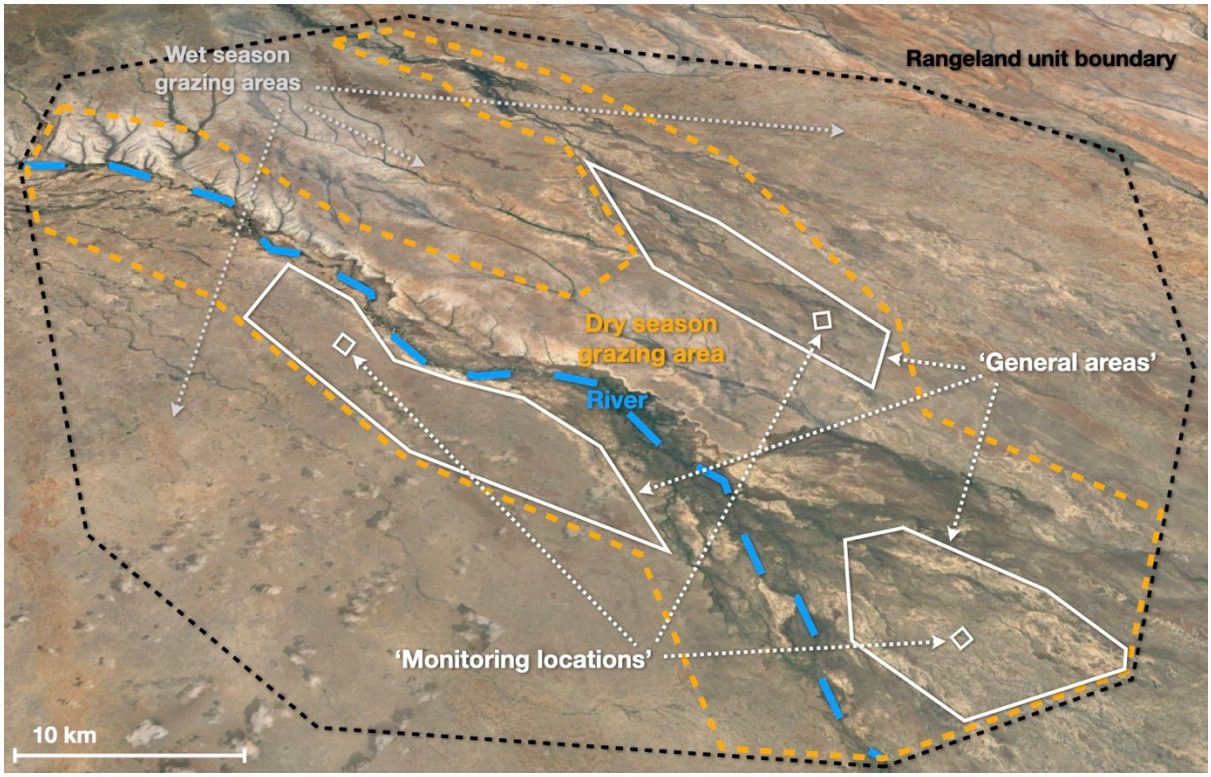


**Figure LP1.** An example of "general areas" and "monitoring locations" that have been selected for baseline monitoring in a single rangeland unit. Here, according to their interest the community has selected to monitor the dry season grazing area (in this case, the other choice is the wet season grazing areas). They selected 3 general areas, placing 1 monitoring location in each. Vegetation, soils, and hydrology are relatively consistent inside each of these general areas. Each monitoring location is representative of its general area.

*STEP 2: Select the "general areas" for monitoring.* "General areas" are selected according to specific criteria given by community sources (Figure LP1). A "general area" matches the following criteria: (i) an area of particular importance as a livestock feed source; (ii) somewhat degraded (but not persistently or stably degraded, and also not in good condition); and (iii) high potential to regenerate productive forage and browse. Degradation varies among rangelands and in its severity, and degradation types include: major erosion/gullies, exotic invasions, bare soil expansion, woody encroachment, and/or poor forage composition. All 3 general areas must be faced by the same type of degradation (not different types), one of the main types of rangeland degradation found in the local area. Finally, in all 3 general areas, vegetation, soils, and hydrology should be somewhat to very consistent (homogeneous), although some variability is unavoidable. After identifying the best general areas according to the criteria above, ask community representatives whether they agree with the final selection. If more than 5 general areas appear to be valid and appropriate, ask the community representatives which general areas they prefer, and note the reasons for their selection.

*STEP 3: Visit the "general areas" and locate the "monitoring locations".* One "monitoring location" is placed inside each "general area" (Figure LP1). A monitoring location must be qualitatively representative of its larger "general area" in terms of soil color (type),

hydrology, and vegetation, such as woody plant cover. A site visit to each general area with community members is conducted to select precisely where the monitoring location is placed inside its general area. The same criteria are again used to select the exact area of the monitoring location: importance for livestock feed, moderate degradation and rangeland condition (not heavily degraded, and not in good condition), and high likely recoverability according to community sources. While representative selection of monitoring locations is generally recommended (due to limited replication), monitoring locations may alternatively be located randomly in some cases (for example, inside general areas that are very large and very homogeneous, making selection difficult).

"Monitoring locations" should usually be separated by a distance of 10 km or more, and must be separated by a minimum of 3 km. Monitoring locations must be located a minimum distance of 200 m away from roads, bomas, settlements, or water points, which are often hotspots of degradation. Monitoring locations must not be located in cropping zones, exclosures, or fenced areas, and must be a minimum distance of 50 m from these areas.

**Spatial arrangement of monitoring locations**

In each of the 3 or more "general areas" selected by the community, 1 "monitoring location" is created (Figure LP1). A "monitoring location" (Figure LP2) consists of two areas: a "monitoring area" of 1.7 ha (210 x 80 m), and a "trial area" of 1.7 ha (210 x 80 m). The monitoring area and the trial area are separated by a minimum of 30 m, up to a maximum of 100 m (in rare cases, < 30 m may be unavoidable). If absolutely necessary, the monitoring and trial areas can be < 210 x 80 m, but the absolute minimum size is 170 x 60 m.

The 1.7-ha "monitoring area" is used primarily for (i) monitoring of rangeland condition outcomes from system-level changes in management, and secondarily (ii) serves as the "control" area for action research restoration trials. The 1.7-ha "trial area" serves as the "treatment" area for a restoration trial, which is applied within the entire trial area *(Note: to test more than one restoration treatment, it is necessary to create a full second trial area of 1.7 ha that is identical to the first, but some modifications to size and spatial arrangement may be required.).*

Each of the 3 monitoring locations have 3 LandPKS plots (50 x 50 m) in the "monitoring area", and 3 LandPKS plots in the "trial area" (Figure LP2), with plots in 3 research blocks, distributed up- and down-slope. Make sure the monitoring and trial areas run up- and down-hill, not across the hill (to control for soil variation). A typical rangeland, with 3 monitoring locations and 6 LandPKS plots per monitoring location, will have a total of 9 monitoring plots, and 9 trial treatment plots.

Assignment of the monitoring area and the trial area is done jointly by researchers or development partners together with the community. At this stage, the roles of researchers and partners are to ensure that the monitoring and trial areas are comparable at baseline, and account for any unique site conditions or confounding variables that may compromise the trial results. The community's role at this stage is to ensure that the trial treatment area can be feasibly protected where needed (protection needs vary among trial protocols), and

that the location or proximity of the trial area does not greatly increase or decrease grazing inside the monitoring area. If there are no practical or scientific reasons for assigning the monitoring and trial areas, they are selected randomly using a coin-toss or the 100$^{ths}$ of seconds on a stopwatch or phone to give random even vs. odd numbers.

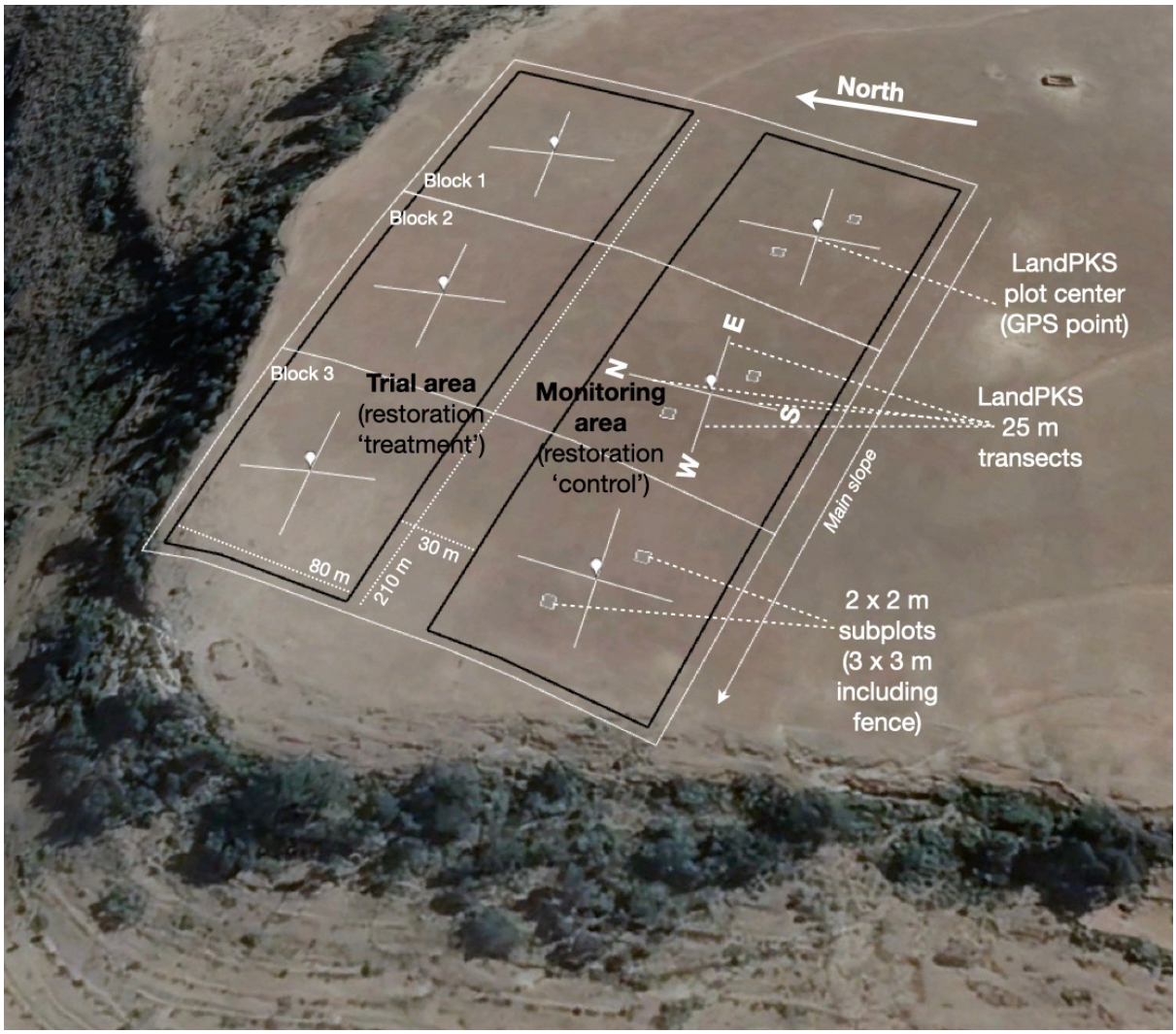


**Figure LP2.** Monitoring location design. Each monitoring location has a "monitoring area" and a "trial area", each with 3 LandPKS plots. Each LandPKS plot has four 25-m transects. Each LandPKS plot in the "monitoring area" has two 2 x 2 m subplots (see Protocol RM2). Blocks 1, 2, and 3 capture soil catena variation.

**Timeline for baseline and outcome measures**

The best time for baseline LandPKS measures is the late wet/growing season, or the early dry/dormant season, around the time of peak standing crop (maximum seasonal biomass). If this timing is not feasible, baseline measures may be taken during other seasons of relevance to livestock producers and system resilience, notably the early dry/dormant season (indicating dry/dormant season forage availability) or the early wet/growing season (indicating rangeland recovery capacity).

Outcome assessment measures must be timed for the same seasonal period in which the baseline was taken, normally the late wet/growing season (or in bimodal rainfall regions, in a different season but with the same seasonal timing—e.g., a baseline in the late short rains can be resampled in the late long rainy season).

Baseline measurements must be taken before the restoration treatment is applied to the trial area. Timing of measurements to assess outcomes from action research restoration trials are guided by trial-specific protocols.

**Information additional to default LandPKS**

Further additional data is recorded at the scale of 50 x 50 m LandPKS plots. These data are to be recorded through a hard copy format (Appendix B) or digital data capture. These data recorded for the entire LandPKS 50 x 50 m plot comprise:

- Ordinal cover of up to 2 plant species of particular importance is needed to document early invasions (which cover measures will miss; definition of important species (invasive, problematic, and/or highly beneficial species) should be the same as for cover measures (see immediately above); even one seedling counts as "presence");
- Ordinal cover of photosynthetic soil crusts/lichen/algae;
- Ordinal density of large (≥ 4 m height, or ≥ 20 cm DBH) trees < 25 m radius from the LandPKS plot center;
- Perceptions of pastoralist producers on land condition to qualitatively track general rangeland health (land condition relative to land potential) and risks to livestock health (parasite/vector suitability); and
- Grazing (and browsing) intensity estimated as mean total livestock units (and wildlife) utilizing the area on a daily basis in the past month.

## C. Protocol RM2. Subplot measures

**Purpose**

Subplots provide for measures of soil carbon, bulk density, and other soil properties, biomass standing crop and production, forage quality, and where appropriate grazing and browsing intensity in terms of biomass change. Quality of forage and browse is useful information for producers and GHG emissions calculations, while separation of biomass components will assist evaluation of remote sensing products.

Subplots are placed and bush-fenced inside the LandPKS plots in the "monitoring area" only (which also serve as "controls" for action research trials). In the "trial area", the subplots are unfenced.

**Subplot nested design**

Within each 50 × 50 m LandPKS plot (see Protocol RM1) in the "monitoring area", two subplots of dimensions 2 × 2 m are placed (Figure SP1). In the monitoring area, each subplot is bush-fenced for a total size of 3 × 3 m (to allow measurement of biomass production) (Figure SP2). One subplot begins at 10 m north and 10 m west of the center of the LandPKS plot, and another at 10 m south and 10 m east. The design is the same in the "trial area", except that the subplots are not fenced.


**Figure SP1.** Subplot locations inside a LandPKS plot.

Each nested 2 × 2 m subplot is divided into four quadrats of dimensions 1 × 1 m (Figure SP2). The NW and SE 1 × 1 m quadrat in each subplot is used for baseline biomass harvest for forage production (in the "monitoring area" only), and will be used in the future for soil outcome measurements. The NE and SW 1 × 1 m quadrat in each subplot is used for soil baseline measures (in both the "monitoring area" and "trial area"), and can additionally be used as either a "before-grazing" or "after-grazing" sample to measure the intensity of a major grazing event (the choice depending on when the NW and SE quadrats were last sampled, and/or when they will be sampled next).

Forage quality samples of grass and browse are taken outside each 2 × 2 m subplot, by dropping a pin (or a stick) in 8 collection points at a distance of 2 m outside the subplot boundary (Figure SP3). Forage quality is sampled only in the "monitoring area" and is not sampled in the "trial area" as this will likely bias the results.

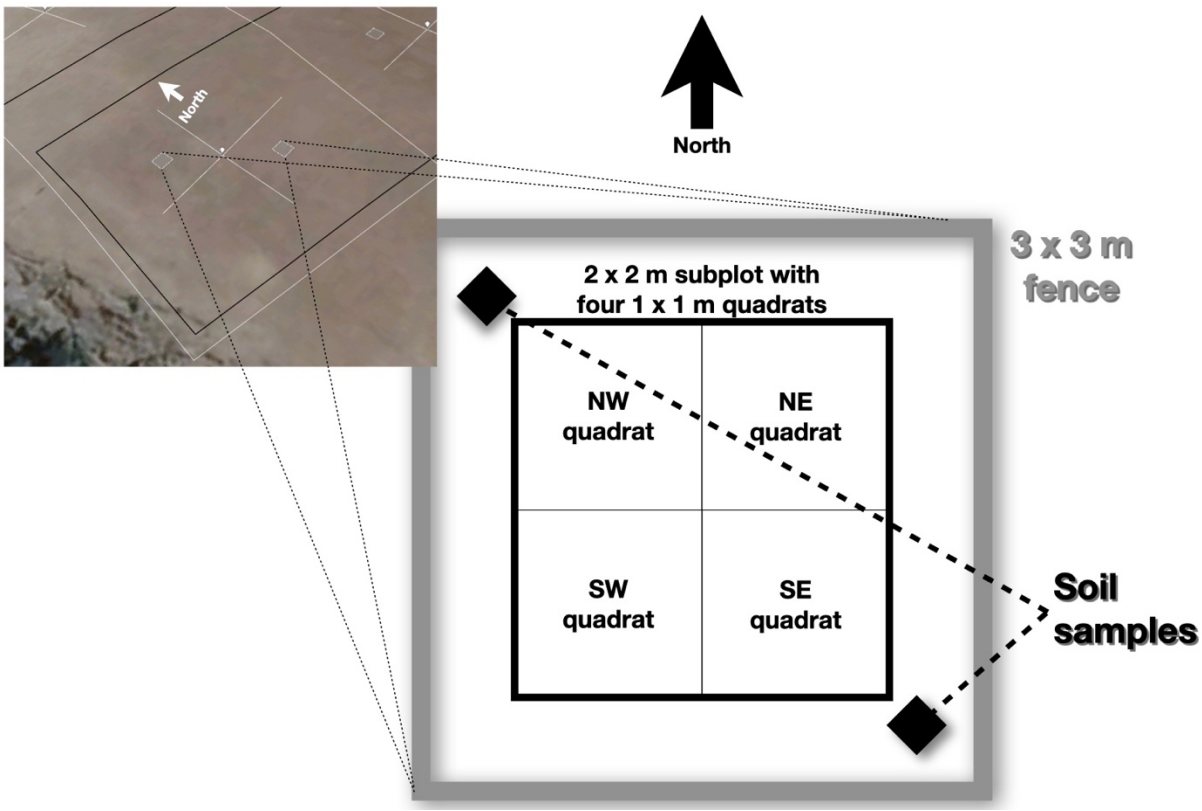


**Figure SP2.** Subplot detailed structure including bush-fence.

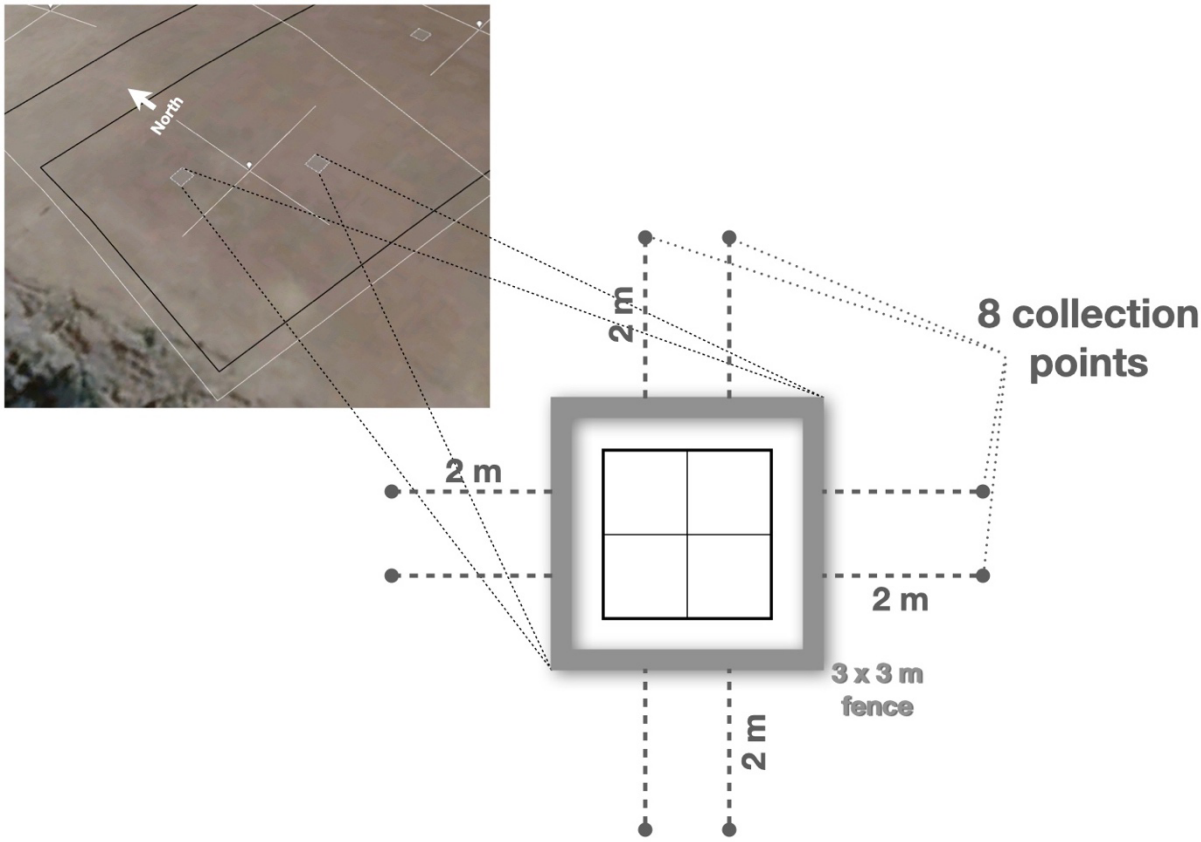


**Figure SP3.** Forage quality sample collection points, located around the subplots.

**Timeline for baseline and outcome measures**

Fences of 3 × 3 m are placed as soon as feasible around the 2 × 2 m subplots (at the latest, at the beginning of the next upcoming wet/growing season) in the "monitoring area" (the "trial area" subplots are not fenced). At the time of fencing in the monitoring area, all herbaceous/grass biomass *produced in previous seasons*, and all leaves of woody trees and shrubs *produced in previous seasons*, are cut from the NW and SE quadrats and removed from the subplot area (to ensure that biomass from previous years or seasons is not counted in production estimates). All herbaceous/grass biomass above 5 cm height is removed, and all tree and shrub leaves < 2 m high (the "browse line"). Fences remain in place for one growing season, or until year-one sampling of peak standing crop—production can only be measured once in areas with unimodal rainfall, while in bi-modal areas it can be measured in either season.

Baseline biomass harvesting for production measures is done at the end of the wet/growing season around the time of peak standing crop in year-one, using the NW and SE quadrats (Figure SP2). Other seasons are not acceptable. Production is measured in the monitoring area only.

The first forage quality samples are taken, in the monitoring area only, whenever feasible and seasonally appropriate. A minimum of one wet/growing season measure and one

dry/dormant season measure are needed over the course of year-one for the forage quality baseline.

To measure outcomes for biomass production in future years, fencing must be repeated in the monitoring area since the baseline fences are removed after one year, or after peak standing crop is sampled for year-one. Grazing intensity can only be measured from year-two onward, as the subplots are fenced in year-one for the biomass production baseline.

Soils can be baselined at any time, as in dry rangelands soil organic matter changes slowly and does not vary seasonally. The best times for soil sampling include at the time of fencing, alongside the first LandPKS measures (Protocol RM1), or at the time of the first biomass production measure. Soils are sampled in both the "monitoring area" and the "trial area" subplots, to enable assessment of restoration outcomes for soil carbon.

**Soil sampling**

The soil baseline is sampled immediately outside the NE and SW 1 × 1 m quadrats of the 2 × 2 m subplots (Figure SP2) in both the "monitoring area" and the "trial area". Outside the NE and SW 1 × 1 m quadrats, a heavy hoe (jembe) is used to cut directly downward into the soil, making a clean, vertical wall roughly 25 cm deep. Bulk density cores are taken by hammering a 5 cm diameter steel bulk density ring soil core horizontally into the vertical wall. Ensure that the bulk density core is not blunted or damaged by stones, as this will alter the volume of the core and reduce the accuracy of bulk density and areal carbon measures.

For each LandPKS plot, 2 sample bags are needed, for two depths, 0-10 cm and 10-20 cm. Outside the NE quadrat of the first subplot, two cores are taken at depths of 0-5 and 5-10 cm, and these cores are combined in one sample bag (labelled 0-10 cm with the LandPKS plot ID). Two more cores are taken at depths of 10-15 and 15-20 cm, and combined in another bag (labelled 10-20 cm with the LandPKS plot ID). The same process is repeated outside the SW quadrat, with the samples placed into the same bags for the correct depth (0-10 cm and 10-20 cm) from the first quadrat. After samples have been taken, the remaining soil is placed back into the hole.

After sampling, the soil sample bags must be opened and kept in a dry, well-ventilated area to allow the soil sample to dry quickly. Once air-dry, the soil samples can be transported to a laboratory for analysis.

Soil outcome measurements might be taken after as little as 3 years, although 5-10 years is recommended for both a larger effect size and greater statistical power. Soil outcome samples are taken outside the NW and SE 1 × 1 m quadrats of the 2 × 2 m subplots (Figure SP2) using the otherwise same procedure as at baseline.

**Biomass harvest for production**

Baseline biomass production is sampled by biomass harvesting, in the "monitoring area" only, in the NW and SE quadrats of each subplot. Outcome measures of biomass production



are taken from the same quadrats of the subplots (NW and SE) in a different, entire future year (or season in bimodal rainfall areas). Biomass production outcomes will require re-fencing the subplots for another full year or season. In regions with bi-modal rainfall such as East Africa, an entire year of two seasons is required for a full annual baseline, but such measures cannot be conducted during any drought that might occur, as there is no biomass to measure. A baseline in arid and semi-arid bi-modal regions could take up to 2 years to obtain sufficient rainfall to provide measures in 2 non-drought seasons. Biomass production must always be measured around the time of maximum biomass for the season (peak standing crop).

To measure biomass production, all grass, and all shrub and tree leaves < 2 m in height (the "browse line") are cut from the NW 1 × 1 m quadrat and piled on a surface for sorting (such as a large bag, etc). The cut grass is separated into live biomass (photosynthetic biomass) and dead biomass (non-photosynthetic biomass). Partially senescent biomass is included in "live biomass". Similarly, the cut shrub leaves are separated into live biomass (photosynthetic biomass) and, if present, dead biomass (non-photosynthetic biomass). For grasses, litter on the soil surface is included, but litter from shrub and tree is excluded. This procedure is repeated for the SE 1 × 1 m quadrat.

For each LandPKS plot, 4 sample bags are needed. Samples from the NW and SE quadrats are combined into a single sample bag for each of the four biomass components: live grass; dead grass; live shrub leaves; and dead shrub leaves. Paper bags (not plastic) must be used (to prevent rotting of the sample).

If large amounts of biomass are present, 50% of each biomass component can be removed and discarded on-site. However, the 50% of biomass that is retained and preserved must be representative of the larger sample (in terms of species/quality/etc), and an equal proportion of biomass should be removed from each of the 2 quadrats in the LandPKS plot. If 50% of the biomass has been removed, this must be recorded on the sample bag (write "50%" on the bag) to allow re-correction.

**Forage quality**

Forage quality samples are taken outside each 2 × 2 m subplot in the "monitoring area" (only), by dropping a pin at 2 m distance from the subplot boundary (Figure SP3), clipping a small sample of the "livestock-edible" grass nearest to the pin, and the "livestock-edible" browse nearest to the pin. The samples are placed in two paper bags, one for grass and one for browse. This procedure is repeated 7 more times around the subplot for a total of 8 clippings. All 8 clippings of grass are placed in one bag, and all 8 clippings of browse are placed in another bag.

This procedure is then repeated for the second subplot, adding the samples to the same bags used for the first subplot. Grass samples are combined in one sample bag for the two subplots, as are browse samples. For each LandPKS plot, 2 sample bags are therefore needed—one for grass and one for browse. Paper bags (not plastic) must be used (to prevent rotting of the sample).



After collection is complete, use the forage quality datasheet (Appendix C) to record the required data on the grass and browse samples.

“Livestock-edible” versus “Livestock-non-edible” forages and browses are defined specifically for each rangeland site as any grass or shrub/tree that is regularly and significantly consumed by any livestock species in the local area (including species not considered “palatable” to livestock, such as low or moderate quality forages and browses that livestock consume when other feeds are not available).

**Biomass harvest for grazing and browsing intensity**

To use biomass harvest for quantitative measurement of grazing and browsing intensity, biomass harvest procedure is the same as above, under “Biomass harvest for production”, with two major differences: timing and the use of the NW and SE subplots versus the NE and SW subplots. Monitoring of grazing and browsing intensity is conducted in the “monitoring area” only, as monitoring of grazing and browsing intensity in the “trial area” would be problematic due to restoration schedules and sampling constraints.

First, since the subplots are fenced for year-one, grazing intensity cannot be measured in these subplots until year-two (although nearby areas could be used to create additional quadrats, but this must be well planned and well documented).

To estimate grazing and browsing intensity, the local timing of use for the monitoring location must be known, to enable biomass harvesting both before and after the main seasonal period during which the monitoring location is used for grazing/browsing. In before-and-after sampling, either diagonal pair of $1 \times 1$ m quadrats (NW/SE or NE/SW) is harvested “before” grazing, and biomass in the other pair is harvested “after” grazing. Which set of plots is used for each must be clearly recorded. The decision to use the NW/SE or NE/SW as “before” grazing depends on when the NW and SE quadrats were last sampled (it should be before the present growing season), and/or will be sampled next (they cannot be sampled again for vegetation outcome monitoring measurements in the same season, or even the following dormant season). Biomass samples are separated according to the four biomass components used in harvesting to measure biomass production: live grass; dead grass; live shrub leaves; and dead shrub leaves; for a total of 4 bags needed per LandPKS plot.

## D. Protocol RM3. Plant diversity and composition

Characterization of plant diversity and composition requires an experienced botanist, and at least one pastoralist knowledgeable on the local area, at minimum. Plant diversity and composition are recorded in both the "monitoring area" and the "trial area" in the center of the LandPKS plots, and in the 2 x 2 m subplots.

First, plant diversity and community composition will be characterized using the tools provided in the LDSF Field Guide (available at: http://landscapeportal.org/documents/2477/). Trees and shrubs are recorded in a circle with a radius of 5.65 m (area 100 $m^2$) at the center of each LandPKS plot, using page 11 in the LDSF Field Guide with 4 LandPKS plots recorded per sheet. All grasses and herbaceous species are recorded using page 13 in the LDSF Field Guide, along 2 transects each 28 m long, and running from South-to-North and East-to-West across the center of the LandPKS plot, by recording the nearest perennial or annual grass or herbaceous species, and its distance from the central transect line.

Second, functional plant community composition is characterized in the 2 x 2 m subplots (see Protocol RM2 for plot design) using two separate datasheets for forages and for browses (Appendix D).

## E. Protocol RM4. Parasite or disease vector abundance

Tick density measures follow Salomon et al. 2020 and Negasa et al. 2014 (Salomon, J., Hamer, S. A., and Swei, A., 2020. A Beginner's Guide to Collecting Questing Hard Ticks (Acari: Ixodidae): A Standardized Tick Dragging Protocol, *Journal of Insect Science* 20(6): 11; 1–8. And Negasa, B., B. Eba, S. Tuffa, B. Bayissa, J. Doyo, and N. Husen. 2014. Control of bush encroachment in Borana zone of southern Ethiopia: effects of different control techniques on rangeland vegetation and tick populations. *Pastoralism* 4(1):18). For other parasites/vectors, protocols to be determined following identification.

Tick density is sampled by the flagging method. The best time for tick sampling is the end of the rainy season, density is highest. However, where restoration schedules do not allow this timing, ticks may be sampled at any time of year as long as later outcome measurements are also conducted with the same seasonal timing. Institutional review may require permissions for collection from local authorities and residents of communal lands.

In each LandPKS plot in both the "monitoring area" and the "trial area" a 1–$m^2$ white cloth or "flag" is dragged along the ground and ground level vegetation of the herbaceous layer. The "flag" is first dragged along a 45–m path running vertically down the North–South center axis of the LandPKS plot, stopping 3 times every 15 m to remove ticks. The cloth is then dragged in one, 15–m path starting 5 m to the west of the center of the LandPKS plot, and the ticks removed. Finally, the cloth is dragged in a 15–m path starting 5 m to the east of the center of the LandPKS plot, and the ticks removed.



At each stop, ticks are removed with fine-tipped forceps, and placed in 1 vial of 70-95% ethanol per LandPKS plot. Tick sampling may be repeated multiple times before and after the restoration treatment to improve accuracy.

## F. Protocol RM5. Root ingrowth cores for belowground biomass production

Belowground biomass production may be measured using the root ingrowth method in the "monitoring area". Where feasible in light of availability of ingrowth mesh bags and access to a nearby laboratory capable of root washing/sieving, 2 root ingrowth "donuts" are placed into the 2 most central soil sampling holes of each LandPKS plot, for a single growing season or rainy season, following Milchunas et al. 2005 (Milchunas, D. G., A. R. Mosier, J. A. Morgan, D. R. Lecain, J. Y. King, and J. A. Nelson. 2005. Root production and tissue quality in a shortgrass steppe exposed to elevated $CO_2$: Using a new ingrowth method. *Plant and Soil* 268:111–122).

The 2 most central soil sampling holes are widened into a circular hole with a 20.3 cm wide diameter and 20 cm depth with clean, straight vertical walls. Stiff, permeable (2 mm x 2 mm mesh ideally) plastic mesh fabric is used to line the inside of the hole. A circular pipe of PVC plastic with diameter 15.2 cm is placed in the center of the hole. The space between the mesh fabric and the PVC pipe is back-filled with root-free sifted soil and gently compacted to approximately the original bulk density by pressing dowels (sticks) into the soil to enable it to settle (Milchunas et al. 2005).

At the end of the growing season, the roots that have grown into the soil inside the mesh bag are harvested. A knife is used to cut progressively downward around the bag, removing the soil carefully without pulling the roots back out of the mesh bag. Transport the roots to the root washing laboratory immediately. Wash and measure root biomass according to Milchunas et al. 2005, immediately after arrival in the laboratory to prevent significant decomposition from occurring.



## G. Appendix A. List of scales, indicators, and protocols for biophysical monitoring.

| Spatial scale of observation | Indicator | Method/ approach | LCSR Protocol |
|---|---|---|---|
| 50 x 50 m plots | Vegetation cover (total and by fraction) | LandPKS | RM1 - LandPKS+ |
| 50 x 50 m plots | Vegetation height | LandPKS | RM1 - LandPKS+ |
| 50 x 50 m plots | Bare soil | LandPKS | RM1 - LandPKS+ |
| 50 x 50 m plots | Land use | LandPKS | RM1 - LandPKS+ |
| 50 x 50 m plots | Grazing/browsing intensity (~cover) | LandPKS | RM1 - LandPKS+ |
| 50 x 50 m plots | Ordinal cover of specific invasive, problematic, and/or highly beneficial species | LandPKS+ | RM1 - LandPKS+ |
| 50 x 50 m plots | Ordinal cover of photosynthetic soil crusts/lichen/algae | LandPKS+ | RM1 - LandPKS+ |
| 50 x 50 m plots | Ordinal density of large trees | LandPKS+ | RM1 - LandPKS+ |
| 50 x 50 m plots | Producer perceptions of land health and risks to livestock health | LandPKS+ | RM1 - LandPKS+ |
| 50 x 50 m plots | Producer perceptions of grazing and browsing intensity | LandPKS+ | RM1 - LandPKS+ |
| 2 x 2 m subplots | Aboveground biomass production — herbaceous + woody | Biomass harvest | RM2 - Subplot measures |
| 2 x 2 m subplots | Photosynthetic vs. non- biomass — herbaceous + woody | Biomass harvest | RM2 - Subplot measures |
| 2 x 2 m subplots | Grazing/browsing intensity (~biomass) | Biomass harvest | RM2 - Subplot measures |
| 2 x 2 m subplots | Forage quality — grass | Biomass clipping | RM2 - Subplot measures |
| 2 x 2 m subplots | Forage quality — browse | Biomass clipping | RM2 - Subplot measures |
| 2 x 2 m subplots | Soil C content to 20 cm | Horizontal coring | RM2 - Subplot measures |
| 2 x 2 m subplots | Soil bulk density to 20 cm | Horizontal coring | RM2 - Subplot measures |
| 2 x 2 m subplots | Soil nutrients and pH from MIR analysis | Horizontal coring | RM2 - Subplot measures |
| 50 x 50 m plots | Plant diversity community composition | Vegetation survey | RM3 – Plant diversity |
| 2 x 2 m subplots | Plant diversity community composition | Vegetation survey | RM3 – Plant diversity |
| 50 x 50 m plots | Parasite or vector abundance (where relevant) | Flagging/ dragging | RM4 - Parasite/disease vector abundance |
| 2 x 2 m subplots | Belowground biomass production | Root ingrowth | RM5 - Root ingrowth |

## H. Appendix B. Datasheet for measures additional to LandPKS

**LandPKS plots (50 x 50 m) — Additional Information**

Rangeland unit (name) _____ Date _____

Monitoring location (A, B, C) _____ Recorder _____

| Area | Block | LandPKS plot ID | Important Species 1 — Name | Important Species 1 — Importance | | | Important Species 1 — Percent (%) cover | | | | Important Species 2 — Name | Important Species 2 — Importance | | | Important Species 2 — Percent (%) cover | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Monit. | 2 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Monit. | 3 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 1 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 2 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 3 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |

| Area | Block | LandPKS plot ID | Rangeland condition (relative to potential) | | | | Tree density < 25 m (≥ 4 m or ≥ 20 cm DBH) | | | | Soil crust/lichen/algae — Percent (%) cover | | | | | | | | Risk of parasites, diseases, vectors | | | Grazing and browsing intensity (daily mean livestock use in the past month; from pastoralists) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | Low | Moderate | High | Cattle____ | Sheep____ | Goats____ |
| Monit. | 2 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | Camels____ | Wildlife____ | Equines____ |
| Monit. | 3 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | | | |
| Trial | 1 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | Low | Moderate | High | Cattle____ | Sheep____ | Goats____ |
| Trial | 2 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | Camels____ | Wildlife____ | Equines____ |
| Trial | 3 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | | | |

Rangeland unit (name) _____ Date _____

Monitoring location (A, B, C) _____ Recorder _____

| Area | Block | LandPKS plot ID | Important Species 1 — Name | Important Species 1 — Importance | | | Important Species 1 — Percent (%) cover | | | | Important Species 2 — Name | Important Species 2 — Importance | | | Important Species 2 — Percent (%) cover | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Monit. | 2 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Monit. | 3 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 1 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 2 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |
| Trial | 3 | | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | Invasive | Problem | Benefit | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 |

| Area | Block | LandPKS plot ID | Rangeland condition (relative to potential) | | | | Tree density < 25 m (≥ 4 m or ≥ 20 cm DBH) | | | | Soil crust/lichen/algae — Percent (%) cover | | | | | | | | Risk of parasites, diseases, vectors | | | Grazing and browsing intensity (daily mean livestock use in the past month; from pastoralists) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | Low | Moderate | High | Cattle____ | Sheep____ | Goats____ |
| Monit. | 2 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | Camels____ | Wildlife____ | Equines____ |
| Monit. | 3 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | | | |
| Trial | 1 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | Low | Moderate | High | Cattle____ | Sheep____ | Goats____ |
| Trial | 2 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | Camels____ | Wildlife____ | Equines____ |
| Trial | 3 | | Poor | Moderate | Good | | None | 1-5 | 5-10 | >10 | 0-1% | 1-15 | 15-35 | 35-60 | 60-100 | | | | | | | | | |

# I. Appendix C. Datasheet for forage and browse quality

**LandPKS plots (50 x 50 m) — Forage and browse quality**

Rangeland unit (name) _____ Date _____

Monitoring location (A, B, C) _____ Recorder _____

**FORAGES — HERBACEOUS GRASSES AND FORBS**

| Area | Block | LandPKS plot ID | Season | Recent rainfall (past 1 month) | Species 1 Name | Species 1 % of sample | Species 2 Name | Species 2 % of sample | Species 3 Name | Species 3 % of sample |
|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Monit. | 2 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Monit. | 3 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 1 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 2 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 3 | | Wet Dry Drought | None Light Heavy | | | | | | |

**BROWSES — WOODY SHRUBS AND TREES**

| Area | Block | LandPKS plot ID | Season | Recent rainfall (past 1 month) | Species 1 Name | Species 1 % of sample | Species 2 Name | Species 2 % of sample | Species 3 Name | Species 3 % of sample |
|---|---|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Monit. | 2 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Monit. | 3 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 1 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 2 | | Wet Dry Drought | None Light Heavy | | | | | | |
| Trial | 3 | | Wet Dry Drought | None Light Heavy | | | | | | |

**2 x 2 m subplots — Forage (all grasses and herbaceous)**

Rangeland unit (name) _____ Date _____

Monitoring location (A, B, C) _____ Recorder _____

| Area | Block | LandPKS plot ID | 2x2 m subplot (NW or SE) | Species name (scientific or vernacular) | Annual / Perennial | Livestock feed value | Percent (%) cover | Average height (cm) |
|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Ann. Peren. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |

**2 x 2 m subplots — Browse (all woody shrubs and trees)**

Rangeland unit (name) _____ Date _____

Monitoring location (A, B, C) _____ Recorder _____

| Area | Block | LandPKS plot ID | 2x2 m subplot (NW or SE) | Species name (scientific or vernacular) | Evergreen / Deciduous | Livestock feed value | Percent (%) cover | Average height (cm) |
|---|---|---|---|---|---|---|---|---|
| Monit. | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Monit. | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 1 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 2 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | NW | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |
| Trial | 3 | | SE | | Evrgn. Decid. | Preferred Edible Non-edible Invasive | 0-1% 1-15 15-35 35-60 60-100 | 0-5 cm 5-20 20-40 40-80 >80 |

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