Response to Feedback from Reviewer 2

Summary:

Reed and coauthors present a well-written study on the impacts of megacarcasses (elephants) to soil biogeochemistry after up to 2 years of decomposition. The authors examined 10 carcass hotspots with 5 carcasses each on two different soil types. They quantified soil major and trace element chemistry as well as plants associated with the hotspots to determine if carcasses influenced soil N and P chemistry and if those elements were subsequently enriched in vegetation. The current version of this manuscript does not adequately describe the methods in enough detail to make the work reproduceable. Additionally, the handling of the data for statistical analyses is strange and non-standard. The discussion needs to be re-written to better emphasize the importance of the work (as framed in the introduction). I think this work has potential to be an important contribution, but there needs to be some major revisions.

AUTHORS' RESPONSE: Thanks for all of your feedback. We have made substantial changes in response to your suggestions, including rewriting the methods section to include more details on the lab analyses. We have also updated our statistical analyses to use the gamma family of generalized linear mixed models, which allows us to run non-normally distributed data without the log transformation. These changes add to the methodological clarity and statistical robustness of this research, and they actually strengthen the major patterns in the results showing the importance of elephant carcasses in savanna nutrient dynamics. Finally, we have updated the text to ensure that the functional distinctiveness of megacarcass relative to smaller carcasses carries through from the introduction to the discussion. All major updates are appended to the end of this document, including methods section 2.3, supplemental tables, and main and supplemental figures.

General comments:

- The importance of this study in adding to our knowledge about nutrient transfer at carrion hotspots is not emphasized clearly in the discussion. The introduction frames how megacarcasses may be "functionally different than smaller carcasses" but never returns to this aspect in the discussion, which is really where this work could add to our knowledge. Adding more to the discussion would help address this issue and would make the impact of the work clearer.

  AUTHORS' RESPONSE: Thanks for the suggestion. We will update the discussion to more clearly link our results to the functional differences between megacarcasses and smaller carrion that we bring up in the introduction. The magnitude of nutrient inputs from megacarcasses, as well as the substantial size and duration of their impact zones, may have important impacts on ecosystem processes that are not seen at smaller carcass sites. For example, we will discuss the potential for positive feedbacks via increased herbivory (Bump, Peterson, & Vucetich, 2009) and predation (Monk et al. 2024) as well as the potential impacts on savanna nutrient heterogeneity (Barton et al. 2013).

- Parts of the results belong in the discussion, and I've tried to highlight those below in specific comments.

AUTHORS' RESPONSE: Thanks for pointing this out. We have edited and/or removed those sentences from the results section and focused on them in the discussion, as described in response to specific comments below.

- The methods need significantly more specific details, highlighted in specific comments.

AUTHORS' RESPONSE: We have substantially updated the methods section in the manuscript (section 2.3) to include specific details on the lab analysis methods. The full updated text for this section is appended to the end of this document (changes are in blue font), and we address specific comments below as well.

- Additionally, there were no control soil or plant samples examined here. Please describe in the methods why there were no controls.

AUTHORS' RESPONSE: The reviewer raises an important point here, and we definitely appreciate the value of control/random sites that other studies of carrion have used. In fact, our original plan was to use random transects as controls (Risch et al. 2020), but during a pilot experiment we realized that high landscape heterogeneity (differences in hill slope, vegetation, water drainage, proximity to termite mounds, etc.), all of which have implications for nutrient distribution across the landscape (Venter et al. 2003; Holdo & McDowell, 2004), made the random transects challenging for interpretation as controls. Instead, we looked at our pilot data to see whether there was a consistent size of the impact site and found that soil nutrients were elevated until about 5-8m away from the center of the carcass site. Past this 5-8m radius, soil nutrients dropped to consistently lower levels, indicative of background concentrations. Thus, we designed the sampling scheme of 0.5m, 2.5m, 5m, 10m, and 15m distances away from the carcass site to capture both the impact of the elephant carcass and the background ("control") concentration of soil nutrients (at the 10m and 15m distance). There was never a significant difference in nutrient concentrations between the 10 and 15m distances, suggesting our sampling scheme successfully captured the transition from the influence of the elephant carcass through to the background level of nutrients in the matrix soils.

We have updated the methods section of the manuscript as follows: "Based on pilot data, we treat the 10-15m distances as controls, sine the high degree of landscape heterogeneity in the system (e.g., differences in hill slope, vegetation, water drainage, proximity to termite mounds) made random transects difficult for interpretation."

Venter FJ, Scholes RJ, Eckhardt HC. Abiotic template and its associated vegetation pattern. In: JT Du Toit, KH Rogers, HC Biggs, eds. The Kruger experience: ecology and management of savanna heterogeneity. Washington, DC, USA: Island Press, 83–129, 2003.

Holdo, R. M. & McDowell, L. R. Termite mounds as nutrient-rich food patches for elephants. Biotropica, 36, 231-239, https://doi.org/10.1111/j.1744-7429.2004.tb00314.x, 2004.

The handling of the data for statistical analyses is non-standard and not clearly justified. If data were non-normally distributed (it seems like some datasets were and some were not), why not just use a non-parametric statistical test rather than log-transforming the data? It is a bit strange to log-transform some data but not all. The approach of adding 0.001 to zero values is also not correct (described below in specific comments).

AUTHORS' RESPONSE: We have updated our model selection procedure to use the gamma family with a log link for our generalized linear mixed models rather than transforming the data beforehand (see RC1, 2.ii).

We have re-run the analyses using 0.005 mg/L as the replacement value for any zeros in the soil ion concentration data, as that is half of the detection limit (0.10 mg/L). The tables with these updated results are appended at the end of this document, but this update did not result in any changes to statistical significance or model performance in the results. We have updated the methods as follows:

"Plant available P, the proportion of water-soluble P in soil that is available for uptake by plants, was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg)…… Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

- The presentation of elemental data for soil and plant composition is non-standardized throughout. Some data (i.e., iron) are presented as mg/kg (is this soil dry weight?), while others are presented as % (Ca% of what?) in the same figure (figure 5 for example). Other data are presented as mg/L (figure 2). Part of this confusion is from the missing details in the methods that clearly explain how these data were generated. In several of the figures there is a statement about back-transformed data, which is also confusing.

AUTHORS' RESPONSE: We appreciate the attention to detail here from the reviewer. We have updated the manuscript so that soil ions, soil anions, and foliar micronutrients are all in mg/kg. Soil and foliar nitrogen are given as percentages, as this is the standard unit of measurement for the instrument used (IRMS) (methodological details appended below). We appreciate you pointing this out and agree that including these methodological details aids greatly in interpretation.

With regards to the comment on back-transformed data, we originally were log-transforming the nutrient data prior to analysis. For aid in visual interpretation of the results, we had displayed the data in its original units. Now that we have updated the

model structure and are no longer log-transforming before analysis, we have removed mentions of back-transformation from the manuscript.

- I can appreciate that finding carcasses that have decomposed for the same amount of time is challenging, but 1 month to 26 months is a huge range of time (at least from what we know from not megacarcasses). The biogeochemical processes occurring at a carcass decaying after 1 month postmortem is very different than a carcass that has been decaying for 26 months (from smaller carcasses). It would be useful to see some of the data, particularly ammonium, plotted as a function of postmortem interval (months) even if that is not a variable that could be included in statistical analyses because of the small sample size. It would also be helpful to see if the postmortem interval for the 10 carcasses is evenly distributed between the two soil types or if one has more fresh carcasses and the other has older carcasses, that could help with interpretation of the results.

AUTHORS' RESPONSE: Thanks for the suggestion! We made a figure showing soil ions (ammonium, nitrate, and phosphate) and respiration potential plotted against carcass age. In these four cases, it is clear that these soil metrics are higher at fresher carcasses. In fact, the trends are so compelling that we have added this figure to the main text (Figure 5). This figure suggests the pattern of elevated soil nutrients that we found may be even stronger when considering younger carcasses given how quickly the nutrients decline with age.

We ran a t-test to test for a difference in mean carcass age across soil types and found no significant difference between the two groups ($P = 0.294$). We will add this finding to the results section.

- I think it may be useful to add some photos to supplemental information (or even the main text) showing what the carcasses/sites looked like (maybe representative images from a fresher carcass and one that is older).

AUTHORS' RESPONSE: Thanks for the suggestion! We have added a supplemental figure (now Figure S1) that shows two carcass sites – one is fresh and on basaltic soil, and the other is older and on granitic soil. The new figure is appended to the end of this document.

Specific comments:

- Lines 99-100: There should be more details provided on the soil type and what makes the granitic soils "nutrient poor" compared to soils developed from a basalt protolith. Because soil type becomes an important part of this study, the details of the soil types need to be expanded in the introduction.

AUTHORS' RESPONSE: Thanks for the suggestion. Kruger National Park has two primary soil types – a clay-rich soil derived from basalt ("basaltic") and a sandy soil

derived from granite ("granitic"). Basalitic soils have clay particles with relatively large surface area, thereby enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014). We agree that these distinctions are important for understanding the impacts of carcass-derived nutrients on different soil types and have updated the methods section as follows: "The two dominant soil types in KNP are granitic soils (inceptisols) and basaltic soils (versitols or andisols) (Khomo et al. 2017). The clay-rich basaltic soils have relatively large surface area, enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014)."

Khomo, L., Trumbore, S., Bern, C. R., & Chadwick, O. A. Timescales of carbon turnover in soils with mixed crystalline mineralogies. SOIL, 3, 17-30, https://doi.org/10.5194/soil-3-17-2017, 2017.

Buitenwerf, R., Kulmatiski, A. & Higgins, S. I. Soil water retention curves for the major soil types of the Kruger National Park. Koedoe, 56, a1228, http://dx.doi.org/10.4102/koedoe.v56i1.1228, 2014.

- Line 132: Include a citation or discuss why soil samples were collected to a depth of 10 cm rather than the upper 5 cm. For decomposition studies, typically the upper 5 cm is examined, not the upper 10 cm.

AUTHORS' RESPONSE: We used a 10cm core to ensure that we captured the soil surface horizon. It is a commonly used depth and is more conservative than shallower sampling. Prior work on the soil impacts of carcasses uses this depth (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024). Moreover, previous work in the same system has shown that soil auger sampling depths of 7.5-10cm are sufficient for detecting differences in N, C, and soil micronutrients (Gray & Bond 2015, Holdo & Mack 2014). We will update the text in the methods to include these references.

Bump, J. K., Peterson, R. O., & Vucetich, J. A. Wolves modulate soil nutrient heterogeneity and foliar nitrogen by configuring the distribution of ungulate carcasses. Ecology, 90, 3159–3167, 2009.

Monk, J. D., Donadio, E., Smith, J. A., Perrig, P. L., Middleton, A. D., & Schmitz, O. J. Predation and Biophysical Context Control Long-Term Carcass Nutrient Inputs in an Andean Ecosystem. Ecosystems, 27, 346–359, 2024.

Gray, E. F. & Bond, W. 2015. Soil nutrients in an African forest/savanna mosaic: Drivers or driven? South African Journal of Botany, 101, 66-72. https://doi.org/10.1016/j.sajb.2015.06.003

Holdo, R. M. & Mack, M. C. 2014. Functional attributes of savanna soils: contrasting effects of tree canopies and herbivores on bulk density, nutrients and moisture dynamics. Journal of Ecology, 102, 1171-1182. https://doi.org/10.1111/1365-2745.12290

- Line 145: More details are needed beyond "measurements of soil ion concentrations". What instrumentation was used? What specific extraction protocol was followed? I'm assuming deionized water was used (1:2 soil to deionized water?), but those details are not provided. How long were samples mixed (shaking platform?), what speed, etc.

AUTHORS' RESPONSE: We have updated the relevant portion of the methods as follows: "We sent 250 g of each soil sample to Eco-Analytica laboratory at the North-West University in Potchefstroom, South Africa for measurements of soil macro-element concentrations of ammonium $[NH_4]^+$, nitrate $[NO_3]^-$, phosphate $[PO_4]^{3-}$, and plant-available P. Samples were air-dried and sieved through < 2mm mesh prior to chemical analysis. Plant available P, the proportion of water-soluble P in soil that is available for uptake by plants, was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and expressed as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and expressed as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L). To convert the nitrate, ammonium, and phosphate units from mg/L to mg/kg, we multiplied by 2, based on the 1:2 soil to water extraction ratio.

- Line 148: "mass spectrometry"—elaborate on what this means with respect to instrumentation used to analyze cations. Here and throughout the methods, please also include what standards were used for the different analysis types.

AUTHORS' RESPONSE: We have updated the relevant section of the methods as follows: "To determine whether soil micronutrients were distinct and elevated at the center of carcass sites relative to soil further from the center, concentrations of sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and phosphorus (P) cations were measured using microwave-assisted digestion. Air-dried and sieved (>2 mm) soil samples, weighed to 0.2 g, were microwaved in 9 ml 65% nitric acid (HNO_3) and 3 ml 32% hydrochloric acid (HCl) according to EPA 3051b in a Milestone, Ethos microwave digester with UP, Maxi 44 rotor. A period of 20 minutes allowed the system to reach 1800 MW at a temperature of 200 °C which was maintained for 15 minutes. After cooling, the samples were brought up to a final volume of 50 ml and analyzed on an Agilent 7500 CE ICP-MS fitted with CRC (Collision Reaction Cell) technology for interference removal. The instrument is optimized using a solution containing Li, Y, Ce, and Tl (1 ppb) for standard low-oxide/low interference levels (≤ 1.5%) while maintaining high sensitivity across the

mass range. The instrument was calibrated using ULTRASPEC® certified custom mixed multi-element stock standard solutions containing all the elements of interest (De Bruyn Spectroscopic Solutions, South Africa). Calibrations spanned the range of 0 – 30 ppm for the mineral elements Ca, Mg, Na, and K and 0 – 0.3 ppm for the rest of the trace elements. Elemental concentrations were expressed as mg/kg."

- Lines 146-150: Clarify if these analyses were conducted on the water extracts.

AUTHORS' RESPONSE: We have clarified as follows: "Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and expressed as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and expressed as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L). To convert the nitrate, ammonium, and phosphate units from mg/L to mg/kg, we multiplied by 2, based on the 1:2 soil to water extraction ratio.."

- Line 152: Were stable isotope analyses conduct on oven-dried soil? 10 g is an exceptionally large amount of soil—how much was actually analyzed with EA-IRMS? Were samples powdered prior to combustion?

AUTHORS' RESPONSE: We have clarified as follows: "Samples were oven-dried at 60°C for 48 hours and milled to a fine powder using a Retsch MM400 mill (Germany). The powdered samples were weighed off (2 – 60 mg) prior to combustion at 950°C."

- Line 154 (and throughout with respect to stable nitrogen isotope results): The authors refer to "^{15}N" measurements, but surely this should be presented as the ratio of 15/14N and in delta notation? In the methods here there also needs to be more description of the standard, the materials used for linearity, and the analytical precision of the instrument.

AUTHORS' RESPONSE: We have changed the notation throughout the manuscript to δ^{15}N. We have updated the methods to include information on standards and precision as follows: "A high organic carbon (HOC) soil standard (0.52 ± 0.02 %N), along with two international reference standards (USGS40 (δ^{15}N -4.52% AIR) and USGS41 (δ^{15}N +47.57% AIR)) were used for calibration. The N elemental content was expressed relative to atmospheric N as N_2 δ^{15}NAIR (‰). The quantification limit for δ^{15}N on the IRMS is 1 nA (nanoAmp), and the quantification limit for %N is 0.06%. The precision for %N was 0.02% and for δ^{15}N is ±0.11%, determined using the HOC standard, which was run multiple times throughout the analysis."

- Line 175: More details on the ICP-MS are needed, including standards, detection limits, etc. Additionally, were these samples digested in nitric acid? Water? How long were they microwaved?

AUTHORS' RESPONSE: We have updated the relevant section of the methods as follows: "To determine whether soil micronutrients were distinct and elevated at the center of carcass sites relative to soil further from the center, concentrations of sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and phosphorus (P) cations were measured using microwave-assisted digestion. Air-dried and sieved (>2 mm) soil samples, weighed to 0.2 g, were microwaved in 9 ml 65% nitric acid (HNO_3) and 3 ml 32% hydrochloric acid (HCl) according to EPA 3051b in a Milestone, Ethos microwave digester with UP, Maxi 44 rotor. A period of 20 minutes allowed the system to reach 1800 MW at a temperature of 200 °C which was maintained for 15 minutes. After cooling, the samples were brought up to a final volume of 50 ml and analyzed on an Agilent 7500 CE ICP-MS fitted with CRC (Collision Reaction Cell) technology for interference removal. The instrument is optimized using a solution containing Li, Y, Ce, and Tl (1 ppb) for standard low-oxide/low interference levels (≤ 1.5%) while maintaining high sensitivity across the mass range. The instrument was calibrated using ULTRASPEC® certified custom mixed multi-element stock standard solutions containing all the elements of interest (De Bruyn Spectroscopic Solutions, South Africa). Calibrations spanned the range of 0 – 30 ppm for the mineral elements Ca, Mg, Na, and K and 0 – 0.3 ppm for the rest of the trace elements. Elemental concentrations were expressed as mg/kg."

- Line 182: Adding some random number to each variable is not a standard way to handle data that are zero in your dataset (or if it is, there is no citation here and I am not familiar with that approach). Typically for geochemical data (like what was generated with ICP-MS), you can replace zero values with ½ the detection limit to remove non-zero data. There are other more technical ways to deal with zero values from a statistical standpoint, but the ½ the detection limit is the easiest and has the longest history of use. Please justify the use of your approach or re-run the analyses following a standard method for handling non-zero data in a geochemical dataset.

AUTHORS' RESPONSE: We have re-run the analyses using 0.005 mg/L as the replacement value for any zeros in the soil ion concentration data, as that is half of the detection limit (0.10 mg/L). The tables with these updated results are appended at the end of this document, but this update did not result in any changes to statistical significance or model performance in the results. We have updated the methods as follows: "Plant available P, the proportion of water-soluble P in soil that is available for uptake by plants, was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg)…… Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

- Line 255: The part of the sentence that reads "…we found evidence that N from carcasses had moved from soils into plants" does not belong in the results section. This is interpretation and should be moved to the discussion.

AUTHORS' RESPONSE: We have edited this sentence to read: "Consistent with our third hypothesis, we found elevated foliar nutrient concentrations at elephant carcass sites." We include interpretation in the first paragraph of the discussion: "Together, these results indicate that carcass-derived nutrients move into soil and subsequently into plants over relatively short time scales, cycling essential nutrients such as N from carrion into the soil and back into aboveground nutrient pools."

- Lines 256-258: Similar comment as above where the content of this sentence is interpretation and should be moved to the discussion.

AUTHORS' RESPONSE: We have deleted the following clause from that sentence: "….indicating that the high N content in leaves closer to the center of a megacarcass site likely had an animal origin."

- Lines 295-297: I'm not quite sure I understand the logic presented here. First, soil microbial biomass was not measured. The respiration potential (through production of CO2) was measured, but heterotrophic activity (which is how respiration can be interpreted) consumes oxygen. I think the phrasing here needs to be re-worked to not imply that the soil respiration (and the communities producing CO2) are not necessarily the same that are driving nitrification.

AUTHORS' RESPONSE: We have edited this sentence to focus on heterotrophic activity rather than nitrification. It now reads: "Soil nitrate (Figure 2B) and soil respiration potential (Figure 3) were also elevated near the center of carcass sites, indicating higher rates of heterotrophic activity (Prosser, 2011)."

- Lines 304-305: There are prior studies that demonstrate the impact of increased organic C during decomposition on soil microbial processes that should be cited here (see studies by DeBruyn and colleagues)

AUTHORS' RESPONSE: Thanks for the suggestion. We have added two relevant citations to these lines from DeBruyn and colleagues.

1. Keenan, S. W., Schaeffer, S. M., Jin, V. L. & DeBruyn, J. M. Mortality hotspots: Nitrogen cycling in forest soils during vertebrate decomposition. Soil Biol. Biochem., 121, 165-176, https://doi.org/10.1016/j.soilbio.2018.03.005, 2018.
2. Keenan, S. W., Schaeffer, S. M., and DeBruyn, J. M.: Spatial changes in soil stable isotopic composition in response to carrion decomposition, Biogeosciences, 16, 3929–3939, https://doi.org/10.5194/bg-16-3929-2019, 2019.

- Lines 310-311: I'm not sure that this is phrased correctly. Phosphorus (predominantly as phosphate) is considered immobile in soil partly because of low solubility because it is often sorbed with Ca, Fe, Al or organics, and the release of P is tightly controlled by soil (or fluid) pH. N does not face the same sorts of sorption immobilization constraints. I think if you rephrased it to clarify that P and N are held within different reservoirs within soils that make them behave differently (and add some citations), that would help.

AUTHORS' RESPONSE: Thanks for the feedback. We have expanded that section to better explain the differences in how N and P are held in soils and agree that this adds clarity. The lines now read: "This lag could occur because phosphate easily forms chemical bonds with other soil ions (e.g., iron and aluminum in acidic soils and calcium in basic soils). Nitrate does not form these bonds and therefore has greater water solubility and soil mobility (Wiersum, 1962; Arai & Sparks, 2007)."

We have also added a second citation:

Aria, Y. & Sparks, D. L. Phosphate reaction dynamics in soils and soil components: a multiscale approach. Adv. Agron., 94, 135-179, https://doi.org/10.1016/S0065-2113(06)94003-6, 2007.

- Lines 324-328: As mentioned above, because the composition of the two soil types were not included, this part of the discussion is not supported by the results. It's unclear if the authors here are trying to say that the basaltic soils contain more nutrients after being impacted by decomposition or if the native state of the soils (background conditions) are more nutrient rich. I think if the introduction described the background chemistry of the two soil types this would be better supported. Additionally, basalt and granite contain different types of minerals and therefore additional sources of elements like P. I don't know what the specific mineralogy is of these two rock types in KNP, but it might be worth exploring. In particular, the presence of apatite (Ca-P bearing mineral) in the granite might also be contributing to elevated P measured in the granite soils.

AUTHORS' RESPONSE: Thanks for bringing this up. We will update the text to clarify that our results confirm a well-established pattern in the literature – that the background state of basaltic soils is more nutrient-rich than granitic soils. What we find interesting here is the significant interaction between soil type and distance with regards to ammonium and phosphate concentrations (Table S1; Figure 2). Ammonium and phosphate levels are elevated at the center of carcass sites in granitic soils relative to basaltic soils, but the difference between soil types disappears as distance from the carcass site increases. These results suggest that the impact of elephant carcasses on these soil ions is greater in the nutrient-poor granitic soils relative to basaltic soils. We will update the text in the discussion to better explain the importance of this soil type by distance interaction. We have also updated the introduction to include more information on the background differences between the two soil types, as described above.

- Figure 5 (and others): I'm a little bit confused by the figure caption. I think it would be better to present this as selected elements plotted as a function of distance. These are not the results of generalized linear mixed models, but the selection of how to present the data were informed by the models.

AUTHORS' RESPONSE: We have changed the text in the figure captions to clarify that we are plotting all the parameters that were included in the top model(s) for a given

response variable (Tables S1-2), which is standard practice. We hope this change in language is clearer.

Revised Methods

2.1 Study system and sample collection

We performed this research in the southern part of the Kruger National Park (KNP), South Africa (24.996 S, 31.592 E, ~275m elevation). The two dominant soil types in KNP are granitic soils (inceptisols) and basaltic soils (versitols or andisols) (Khomo et al. 2017). The clay-rich basaltic soils have relatively large surface area, enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014; Rughöft et al. 2016). The landscape at KNP is a mix of savanna grasslands and broadleaf woodlands, with an overstory dominated by trees from the genus *Combretum* (red bushwillow, *C. apiculatum*; russet bushwillow, *C. hereroense*; leadwood, *C. imberbe*) and trees formerly known as acacias (knobthorn, *Senegalensis nigrescens*; umbrella thorn, *Vachellia tortillis*). The park hosts a full suite of African savanna animals, including ~30,000 elephants (*Loxodonta africana*) (Coetsee & Ferreira, 2023), with a mortality rate of ~2% (~600 elephants per year). The targeted region of KNP has a high density of scavengers and predators, including white-backed vultures (*Gyps africanus*), spotted hyenas (*Crocuta crocuta*), and lions (*Panthera leo*) (Owen-Smith & Mills, 2007).

During the wet season in March 2023, we identified ten elephant carcass sites (1-26 months post-death), five on relatively nutrient-rich basaltic soil and five on nutrient-poor granitic soil. KNP section rangers provided precise GPS locations of where elephant carcasses had been found. Most elephants died of old age, illness, injury, or, in the case of one young bull, territorial fighting. These sites were recognizable *in situ* by a persistent bonefield, undigested gut contents,

and an absence of herbaceous vegetation. At each site, we hammered a rebar post into the center of the megacarcass disturbance and ran 15 m transects out from the post in each of the four cardinal directions. Based on pilot data, we treat the 10-15m distances as controls, sine the high degree of landscape heterogeneity in the system (e.g., differences in hill slope, vegetation, water drainage, proximity to termite mounds) made random transects difficult for interpretation. We collected green leaf material from *Urochloa mosambicensis,* a common and abundant palatable grass species, and used an auger to collect soil samples to a depth of 10 cm at five points along each transect (0.5, 2.5, 5, 10, and 15 m). We pooled and homogenized the samples to yield one composite leaf and one composite soil sample per sampling distance from each carcass site. Soil samples were sieved in a 5-mm metal sieve which was cleaned in between samples with 70% ethanol. Soil samples were stored in a cooler during fieldwork. On the day they were collected, we used 5 g of each soil sample for soil respiration measurements (described below). The rest of each sample was stored plastic bags in a -20°C freezer until nutrient analyses; they were stored in coolers with ice blocks during the transition from the freezer at the field site to the freezers at the labs. Leaf samples were stored in paper bags at room temperature until dried for analyses (see below).

2.3 Hypothesis testing

We tested our first hypothesis that elephant megacarcass decomposition would release nutrients into the soil by performing soil nutrient analyses. We sent 250 g of each soil sample to Eco-Analytica laboratory at the North-West University in Potchefstroom, South Africa for measurements of soil macro-element concentrations of ammonium $[NH_4]^+$, nitrate $[NO_3]^-$, phosphate $[PO_4]^{3-}$, and plant-available P. Samples were air-dried and sieved through < 2mm

mesh prior to chemical analysis. Plant available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and expressed as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and expressed as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L). To convert the nitrate, ammonium, and phosphate units from mg/L to mg/kg, we multiplied by 2, based on the 1:2 soil to water extraction ratio.

To determine whether soil anions were distinct and elevated at the center of carcass sites relative to soil further from the center, concentrations of sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and phosphorus (P) cations were measured using microwave-assisted digestion. Air-dried and sieved (>2 mm) soil samples, weighed to 0.2 g, were microwaved in 9 ml 65% nitric acid (HNO_3) and 3 ml 32% hydrochloric acid (HCl) according to EPA 3051b in a Milestone, Ethos microwave digester with UP, Maxi 44 rotor. A period of 20 minutes allowed the system to reach 1800 MW at a temperature of 200 °C which was maintained for 15 minutes. After cooling, the samples were brought up to a final volume of 50 ml and analyzed on an Agilent 7500 CE ICP-MS fitted with CRC (Collision Reaction Cell) technology for interference removal. The instrument is optimized using a solution containing Li, Y, Ce, and Tl (1 ppb) for standard low-oxide/low interference levels (≤ 1.5%) while maintaining high

sensitivity across the mass range. The instrument was calibrated using ULTRASPEC® certified custom mixed multi-element stock standard solutions containing all the elements of interest (De Bruyn Spectroscopic Solutions, South Africa). Calibrations spanned the range of 0 – 30 ppm for the mineral elements Ca, Mg, Na, and K and 0 – 0.3 ppm for the rest of the trace elements. Elemental concentrations were expressed as mg/kg.

Finally, to determine whether elevated N levels in soils were derived from the carcass, we sent 10 g of each sample to the BIOGRIP laboratory within the Central Analytical Facility at Stellenbosch University for measurements of soil %N and $\delta^{15}N$, obtained using a Vario Isotope Select Elemental Analyzer connected to a thermal conductivity detector and an Isoprime precisions isotope ratio mass spectrometer (IRMS). Samples were oven-dried at 60°C for 48 hours and milled to a fine powder using a Retsch MM400 mill (Germany). The powdered samples were weighed off (2 – 60 mg) prior to combustion at 950°C. The gasses were reduced to N_2 (undiluted) in the reduction column, which was held at 600°C. A high organic carbon (HOC) soil standard (0.52 ± 0.02 %N), along with two international reference standards (USGS40 ($\delta^{15}N$ -4.52% AIR) and USGS41 ($\delta^{15}N$ +47.57% AIR)) were used for calibration. The N elemental content was expressed relative to atmospheric N as N_2 $\delta^{15}N$AIR (‰). The quantification limit for $\delta^{15}N$ on the IRMS is 1 nA (nanoAmp), and the quantification limit for %N is 0.06%. The precision for %N was 0.02% and for $\delta^{15}N$ is ±0.11%, determined using the HOC standard, which was run multiple times throughout the analysis.

To test our second hypothesis that nutrient inputs to the soil would stimulate microbial activity, we measured soil organic C, water content, and microbial respiration potential. We sent 10 g of each sample to the BIOGRIP laboratory for measurements of soil organic C using a Vario TOC Cube (Elementar, Germany). Samples (dried and milled as above) were weighed off (10 –

60 mg), acidified using 10% HCl to remove the total inorganic C (carbonates), and dried overnight at 60°C. All samples were analyzed through combustion at 950°C. The released CO_2 was measured by a non-dispersive infrared (NDIR) sensor. A high organic C (7.45 ± 0.14 %C) soil standard from Elemental Microanalysis Ltd (UK) was included during the analysis. The quantification limit for %C is 0.14%. The precision for the %C was 0.09% and was determined using the low organic C (LOC) standard (1.86 ± 0.14 %C), which was run multiple times throughout the analysis.

To quantify soil respiration and water content, we used an incubation method (Lemoine et al. 2024) in which 5 g (± 0.2 g) of each sample was placed into a 100 ml clear glass bottle, sealed, and flushed with CO_2-free air. Following flushing, we incubated the bottles for one hour at 25°C. We then recorded CO_2 concentrations using an LI-850 CO_2/H_2O infrared gas analyzer. After soil respiration measurements, we determined sample dry weight by drying each sample at 60°C for 24-48 hours until stable mass was achieved. We subtracted dry weight from starting weight to obtain soil water content. Finally, we used the dry weights and the Ideal Gas Law to standardize all respiration measurements to CO_2 $\mu g\ h^{-1} g\ dry\ soil^{-1}$.

To test our third hypothesis that carcass-derived nutrients would move from soil into plants, we measured foliar nutrient concentrations in *U. mosambicensis*. Two grams of each dried leaf sample was sent to the BIOGRIP laboratory for preparation and measurements of %N and $\delta^{15}N$ via stable isotope analysis as described above. A Sorghum flour standard (1.47 ± 0.25 %N) from Elemental Microanalysis Ltd (UK) was used for calibration, along with two international reference standards (USGS40 and USGS41). The quantification limit for $\delta^{15}N$ on the IRMS is 1 nA, and the quantification limit for %N is 1.3%. The precision for the %N was 0.02% and for $\delta^{15}N$ is ±0.08‰. Limits were determined using the sorghum flour standard, which was run

multiple times throughout the analysis. Additionally, we sent 5 g per sample to Cedara Analytical Services Laboratory to quantify micronutrients in grass tissue (P, Na, Mg, K, Ca, and Fe) using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES 5800, Agilent, USA). Samples were dried (110°C overnight) and milled to a fine powder. Subsamples (0.5 g) were ashed at 450°C for 4 hours, and the ash was re-wet using 2 mL conc. HCl (32%). Samples were evaporated to dryness then re-suspended in 25 mL 1M HCl before filtering. Lastly, the filtrate was diluted with de-ionized water in a ratio of 5:20 filtrate to water. To calibrate the ICP-OES, solutions containing known amounts of each element were measured (10-20 ppm for Na and C, 200-1500 ppm for Fe, 0.5-3.75% for K, and 0.125-0.5% for P), prepared from 1000 ppm primary single standards. At three of the ten sites, we did not find sufficient plant material at the central point for analysis, resulting in a sample size of N = 7 for the center (distance = 0-0.5m) measurement for leaf nutrient analyses.

To test whether each response variable for the three hypotheses was significantly associated with soil type and/or distance from the carcass center, we performed a model selection procedure. For each response variable, we ran five generalized linear mixed models using the gamma family (link = log) in the package *lme4* (Bates et al. 2015): (*i*) soil type + distance + soil type × distance interaction, (*ii*) soil type + distance, (*iii*) soil type, (*iv*) distance, and (v) a null model indicating no significant difference in slope or intercept after accounting for carcass site. All models included carcass site as a random effect to account for individual variation. Each model included 50 observations (10 sites x 5 distances per site). For samples in which the nutrient level was listed as 0 or undetectable, we accounted for the uncertainty by using half the detection level. The narrow distribution of ages (1-26 months since death) with the sample size of N = 10 sites made testing for the effect of age challenging, so we did not include carcass age

in the models. We compared the models for each response variable using Akaike Information Criterion (AICc). Models with a $\Delta AICc \leq 2$ were considered roughly equivalent in fit (Burnham and Anderson, 2002).

In addition to these models, for our second hypothesis we regressed soil respiration potential against soil organic C, expecting that the two would be positively correlated. We ran a generalized linear mixed model with soil respiration potential as the response variable. The model included soil organic C + distance + soil type, with carcass site as a random effect. We did not include an interaction with soil type in this model due to sample size restrictions. Respiration potential and organic C were both log-transformed to achieve normality.

To determine whether leaf and soil micronutrient composition differed with distance and soil type, we ran permutational analysis of variance (perMANOVA) in *vegan* (Oksanen et al. 2022). We ran the same model separately for soil and leaf micronutrient composition (soil type + distance). To determine which micronutrients contributed most to compositional differences across distances and soil types, we calculated samplewise Bray-Curtis dissimilarity and performed principal component analysis. Finally, we ran linear models to test for correlations between leaf and soil concentrations of each micronutrient. Each model included distance as a covariate and site as a random effect.

All statistical analyses were performed in R version 4.2.1 (R Core Team, 2022).

Revised Main Figures

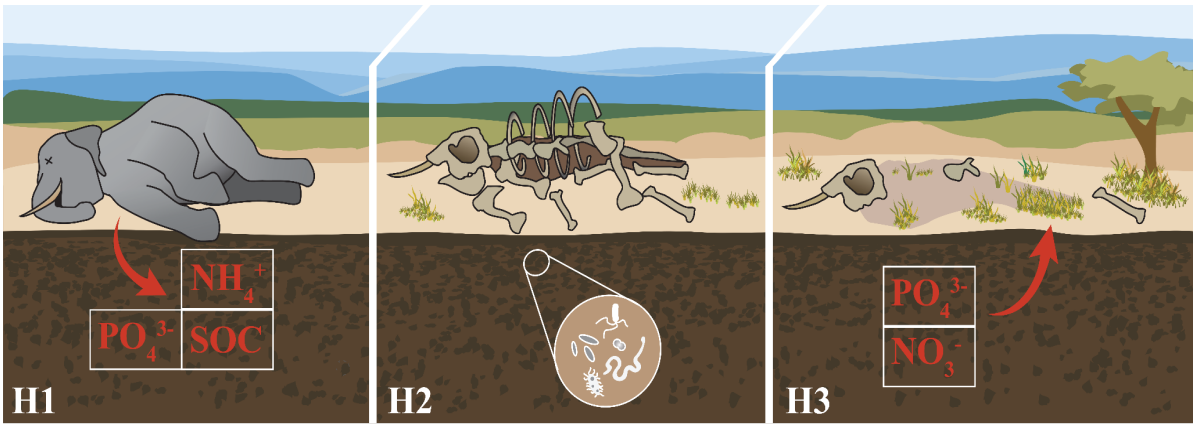


Figure 1. Hypothesized impacts of elephant megacarcasses on soil and plant nutrients. First (H1), we hypothesized that elephant carcasses would release pulses of nutrients into the soil, resulting in higher concentrations of soil nutrients such as nitrogen (ammonium, $[NH_4]^+$), phosphorus (phosphate, $[PO_4]^{3-}$), and soil organic C. Second (H2), we hypothesized that C inputs from the carcass would result in increased soil microbial respiration potential. Third (H3), we hypothesized that plants would take up nutrients from the carcass soil, resulting in plants with distinct nutrient profiles and increased concentrations of key limiting nutrients such as N and P. Image credit: Kirsten Boeh.

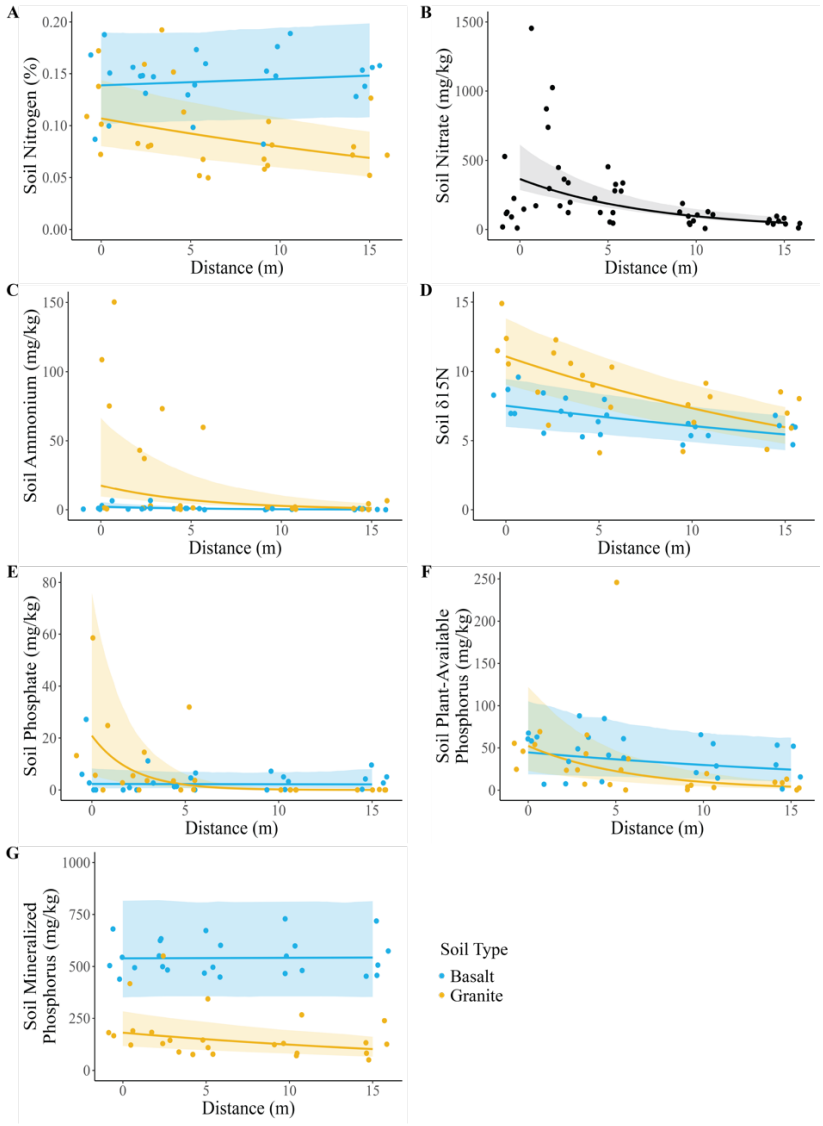


Figure 2. Soil N and P responses to elephant carcasses. (A) Soil N (%) was greater in basaltic soils, and in granitic soils it decreased with distance from the carcass site. (B) Soil nitrate nitrogen decreased with distance but did not differ with soil type. (C) Soil ammonium nitrogen and (D) $\delta^{15}N$ were both greater in granitic soils and decreased with distance from the carcass. (E) Soil phosphate, (F) plant-available P, and (G) mineralized P decreased with distance in granitic soils but not basaltic soils. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap. Lines show predictions calculated from the top model. Shading indicates the 95% confidence interval.

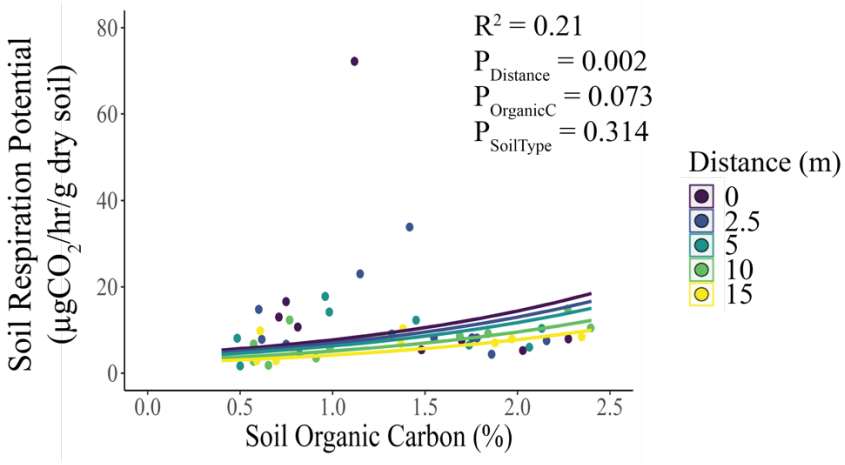


Figure 3. Soil respiration potential was marginally positively correlated with soil organic C (%) and decreased significantly with distance from the carcass. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap. Lines represent model predictions.

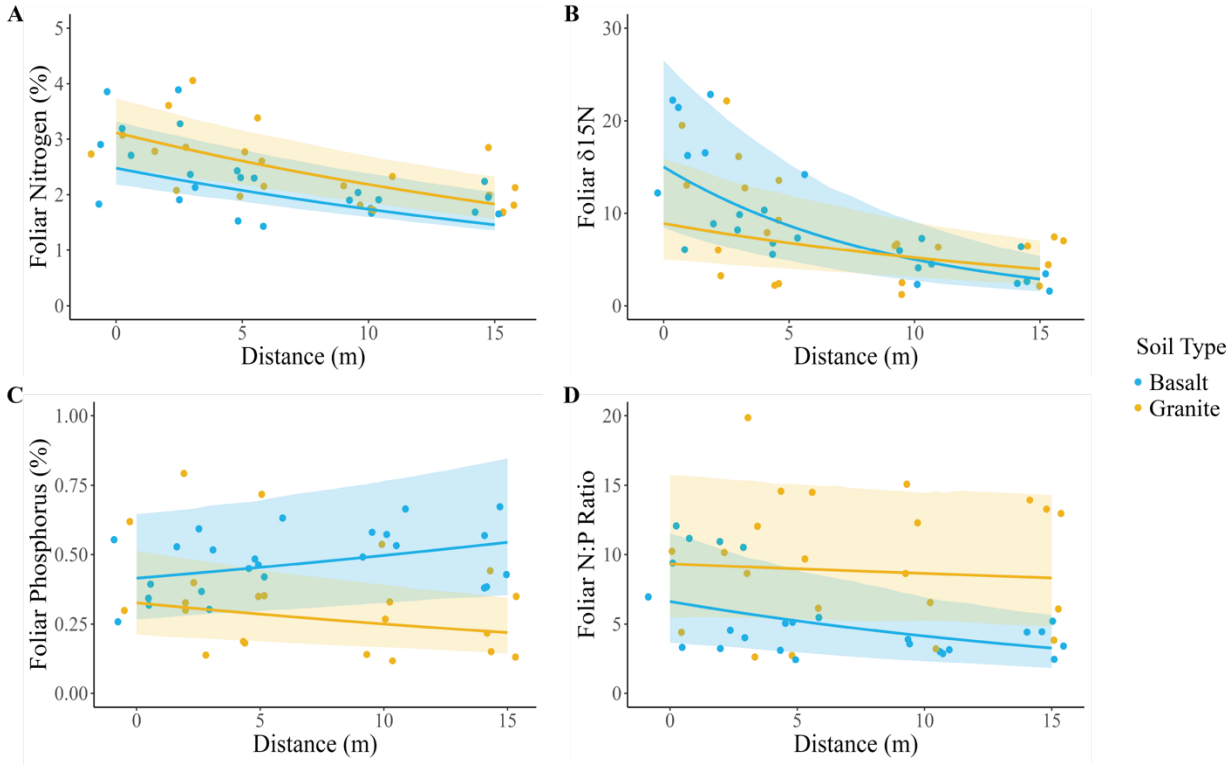
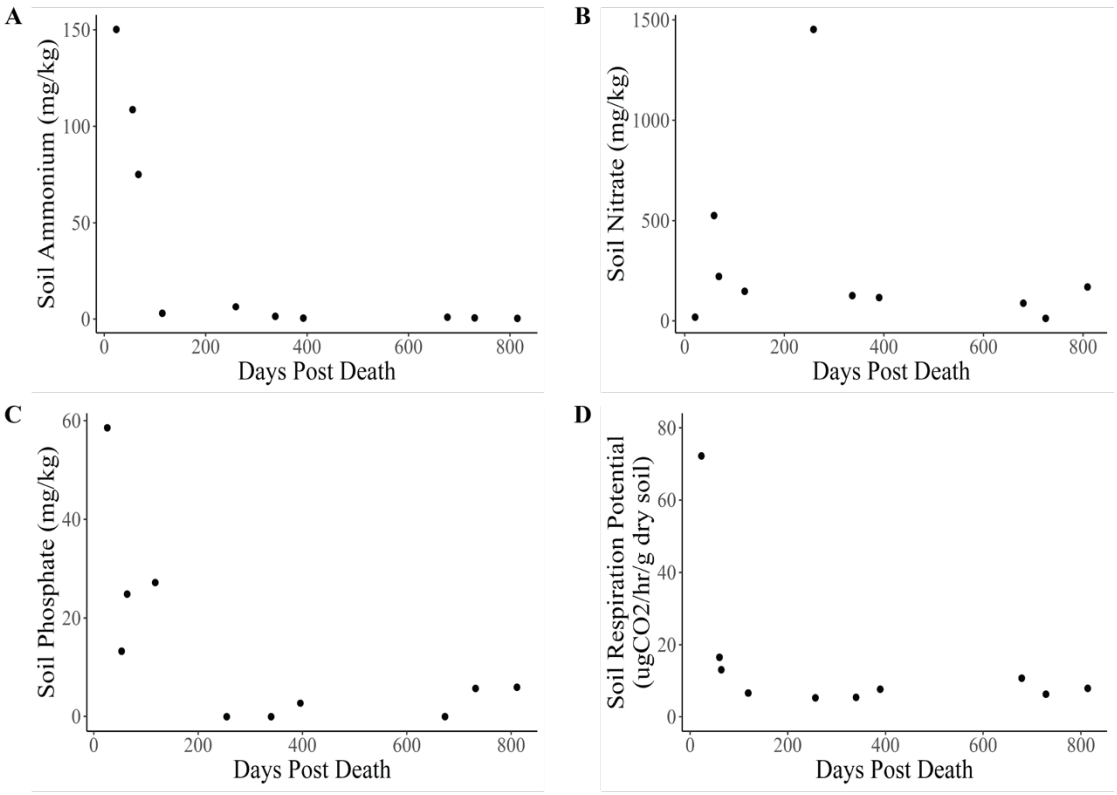


Figure 4. Foliar N and P responses to elephant carcasses. (A) Foliar %N and (B) $\delta^{15}N$ both decreased with distance from the carcass center. (C) Foliar P was greater in basaltic soils and decreased with distance in granitic soils. (D) Foliar N:P ratio was greater in granitic soils and decreased with distance from the carcass center. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap. Lines show predictions calculated from the top model. Shading indicates the 95% confidence interval. Three of the ten sites had bare ground at the 0 m distance, resulting in a sample size of 7 sites for that distance and 10 for the other distances.



Relationship between carcass age and key metrics (soil ion concentrations and respiration potential). (A) Soil ammonium, (B) soil nitrate, (C) soil phosphate, and (D) soil respiration potential are all higher at fresher carcass sites. Point respresent values at the center of the carcass site (distance = 0-0.5m).

Figure 5. Relationship between carcass age and key soil metrics (soil ion concentrations and respiration potential). (A) Soil ammonium, (B) nitrate, (C) phosphate, and (D) respiration potential are all higher at fresher carcass sites. Points represent individual measurements taken at the center of the carcass site (distance = 0-0.5m).

Revised Supplemental Tables

Table S1. Generalized linear mixed model results for soil variables. The same five models were run for each response variable, including a null model, and each included site as a random effect to account for repeat measurements. AICc is Akaike's Information Criterion, and ΔAICc is the difference between a given model and the best fit model for that response variable. Cum.Wt stand for cumulative weight; it gives the sum of Akaike's weights and indicates the likelihood that the models up to that point are the best in the set. Models with a ΔAICc value of 2 are considered roughly equivalent in fit and are italicized. Marginal R^2 is the proportion of variance explained by both fixed and random effects in a model, and conditional R^2 is the proportion of variance explained by fixed effects. Coefficients (± standard error) are shown for each predictor and model and are in log units. Rows are organized in blocks by response variable. Within blocks, models are listed in order of increasing ΔAICc.

Model	**Model Fit**					**Coefficients ± *SE***		
	AICc	**ΔAICc**	**Cum.Wt**	**Mar. R^2**	**Con. R^2**	**Soil**	**Distance**	**Soil × Distance**
Nitrogen (%)								
Soil × Distance	*-227.32*	*0.00*	*0.99*	*0.54*	*0.74*	*-0.26 ± 0.22*	*0.00 ± 0.01*	*-0.03 ± 0.01*
Soil + Distance	-216.13	11.20	1.00	0.46	0.67	-0.48 ± 0.21	-0.01 ± 0.00	
Distance	-214.95	12.37	1.00	0.04	0.52		-0.01 ± 0.00	
Soil	-212.36	14.97	1.00	0.40	0.62	-0.47 ± 0.21		
Null	-211.23	16.09	1.00					
δ15N								
Soil × Distance	*180.87*	*0.00*	*0.77*	*0.55*	*0.70*	*0.39 ± 0.16*	*-0.02 ± 0.01*	*-0.02 ± 0.01*
Soil + Distance	184.66	3.79	0.88	0.50	0.66	0.26 ± 0.15	-0.03 ± 0.00	
Distance	184.67	3.79	1.00	0.34	0.60		-0.03 ± 0.00	
Soil	219.35	38.47	1.00	0.20	0.34	0.28 ± 0.14		
Null	219.96	39.09	1.00					
Nitrate (mg/kg)								
Distance	*624.84*	*0.00*	*0.70*	*0.48*	*0.52*		*-0.14* ± 0.02	

Soil + Distance	627.06	2.23	0.93	0.48	0.52	-0.14 ± 0.27	-0.14 ± 0.02	
Soil × Distance	629.51	4.67	1.00	0.48	0.52	-0.24 ± 0.39	-0.14 ± 0.03	0.02 ± 0.04
Null	649.77	24.93	1.00					
Soil	651.82	26.99	1.00	0.01	0.04	-0.18 ± 0.31		
Ammonium (mg/kg)								
Soil + Distance	*219.52*	*0.00*	*0.65*	*0.58*	*0.77*	*2.49* ± 0.66	*-0.18* ± 0.03	
Soil × Distance	*220.94*	*1.43*	*0.97*	*0.60*	*0.77*	*2.91* ± 0.73	*-0.15* ± 0.04	*-0.07* ± 0.06
Distance	225.87	6.35	1.00	0.21	0.77		-0.18 ± 0.02	
Soil	244.57	25.05	1.00	0.34	0.70	2.51 ± 0.76		
Null	249.38	29.86	1.00					
Phosphate (mg/kg)								
Soil × Distance	*167.99*	*0.00*	*0.98*	*0.52*	*0.79*	*2.20 ± 0.96*	*0.00 ± 0.05*	*-0.46 ± 0.08*
Soil + Distance	178.68	10.69	1.00	0.18	0.18	-0.38 ± 0.70	-0.14 ± 0.06	
Null	180.65	12.66	1.00					
Soil	Model did not converge							
Distance	Model did not converge							
Plant Available Phosphorus (mg/kg)								
Soil × Distance	*447.18*	*0.00*	*0.94*	*0.34*	*0.63*	*0.16 ± 0.62*	*-0.04 ± 0.03*	*-0.13 ± 0.04*
Distance	453.68	6.50	0.98	0.20	0.55		-0.10 ± 0.02	
Soil + Distance	454.80	7.62	1.00	0.26	0.55	-0.66 ± 0.55	-0.11 ± 0.02	
Null	467.35	20.17	1.00					
Soil	469.19	22.01	1.00	0.03	0.30	-0.35 ± 0.47		
Mineral Phosphorus (mg/kg)								
Soil × Distance	*537.77*	*0.00*	*1.00*	*0.86*	*0.95*	*-1.09 ± 0.32*	*0.00 ± 0.00*	*-0.04 ± 0.01*
Soil + Distance	560.48	22.71	1.00	0.82	0.92	-1.35 ± 0.31	-0.02 ± 0.00	
Distance	566.38	28.61	1.00	0.04	0.76		-0.02 ± 0.00	
Soil	573.55	35.78	1.00	0.78	0.89	-1.33 ± 0.31		
Null	579.62	41.85	1.00					
Sodium (mg/kg)								
Soil × Distance	*438.56*	*0.00*	*0.73*	*0.29*	*0.59*	*0.22 ± 0.35*	*-0.03 ± 0.01*	*-0.04 ± 0.02*
Distance	441.09	2.53	0.94	0.22	0.54		-0.05 ± 0.00	
Soil + Distance	443.53	4.97	1.00	0.22	0.54	-0.06 ± 0.35	-0.05 ± 0.01	
Null	464.02	25.45	1.00					

Soil	466.38	27.82	1.00	0.00	0.34	0.00 ± 0.00		
Potassium (mg/kg)								
Soil × Distance	*676.07*	*0.00*	*0.94*	*0.29*	*0.81*	*-0.23 ± 0.42*	*0.01 ± 0.00*	*-0.02 ± 0.01*
Null	682.93	6.86	0.97					
Soil	684.55	8.48	0.99	0.25	0.78	-0.37 ± 0.41		
Distance	685.17	9.10	1.00	0.00	0.72		0.00 ± 0.00	
Soil + Distance	686.89	10.82	1.00	0.26	0.78	-0.37 ± 0.41	0.00 ± 0.00	
Calcium (mg/kg)								
Soil	*749.09*	*0.00*	*0.60*	*0.82*	*0.94*	*-1.45 ± 0.41*		
Soil + Distance	*751.01*	*1.92*	*0.83*	*0.82*	*0.94*	*-1.45 ± 0.01*	*0.00 ± 0.00*	
Soil × Distance	753.00	3.91	0.91	0.82	0.94	-1.42 ± 0.41	0.00 ± 0.01	-0.01 ± 0.01
Null	753.55	4.46	0.97					
Distance	755.37	6.27	1.00	0.00	0.81		0.00 ± 0.00	
Iron (mg/kg)								
Soil	*914.44*	*0.00*	*0.67*	*0.88*	*0.96*	*-1.22 ± 0.28*		
Soil + Distance	916.83	2.39	0.87	0.88	0.96	-1.22 ± 0.28	0.00 ± 0.00	
Soil × Distance	918.54	4.10	0.95	0.88	0.96	-1.19 ± 0.28	0.00 ± 0.00	0.00 ± 0.01
Null	920.27	5.83	0.99					
Distance	922.55	8.11	1.00	0.00	0.82		0.00 ± 0.00	
Magnesium (mg/kg)								
Soil	*700.88*	*0.00*	*0.63*	*0.87*	*0.96*	*-1.53 ± 0.37*		
Soil + Distance	703.33	2.45	0.81	0.87	0.96	-1.53 ± 0.37	0.00 ± 0.00	
Soil × Distance	703.97	3.09	0.95	0.88	0.96	-1.48 ± 0.37	0.00 ± 0.00	-0.01 ± 0.01
Null	706.40	5.52	0.99					
Distance	708.75	7.87	1.00	0.00	0.84		0.00 ± 0.00	
Water (mmol/mol)								
Null	*111.87*	*0.00*	*0.32*					
Distance	*112.09*	*0.22*	*0.61*	*0.03*	*0.38*		*0.02 ± 0.01*	
Soil	*112.92*	*1.05*	*0.80*	*0.12*	*0.40*	*0.45 ± 0.38*		
Soil + Distance	*113.27*	*1.40*	*0.96*	*0.14*	*0.42*	*0.45 ± 0.38*	*0.02 ± 0.01*	
Soil × Distance	115.86	3.99	1.00	0.14	0.42	0.44 ± 0.42	0.02 ± 0.02	0.00 ± 0.03
pH								
Soil × Distance	*55.04*	*0.00*	*0.37*	*0.07*	*0.44*	*0.05 ± 0.07*	*0.00 ± 0.00*	*-0.01 ± 0.00*
Null	*55.26*	*0.22*	*0.71*					

Distance	*56.94*	*1.90*	*0.86*	*0.01*	*0.38*		*0.00 ± 0.00*	
Soil	57.63	2.59	0.96	0.00	0.37	0.00 ± 0.07		
Soil + Distance	59.41	4.37	1.00	0.01	0.38	0.00 ± 0.00	0.00 ± 0.00	

Table S2. Generalized linear mixed model results for leaf variables. The same five models were run for each response variable, including a null model, and each included site as a random effect to account for repeat measurements. AICc is Akaike's Information Criterion, and ΔAICc is the difference between a given model and the best fit model for that response variable. Cum.Wt stand for cumulative weight; it gives the sum of Akaike's weights and indicates the likelihood that the models up to that point are the best in the set. Models with a ΔAICc value of 2 are considered roughly equivalent in fit and are italicized. Marginal R^2 is the proportion of variance explained by both fixed and random effects in a model, and conditional R^2 is the proportion of variance explained by fixed effects. Coefficients (± standard error) are shown for each predictor and model and are in log units. Rows are organized in blocks by response variable. Within blocks, models are listed in order of increasing ΔAICc.

Model	**Model Fit**					**Coefficients ± *SE***		
	AICc	**ΔAICc**	**Cum.Wt**	**Mar. R^2**	**Con. R^2**	**Soil**	**Distance**	**Soil × Distance**
Nitrogen (%)								
Distance	*56.12*	*0.00*	*0.64*	*0.40*	*0.60*		*-0.03* ± 0.00	
Soil + Distance	57.79	1.67	0.92	0.43	0.61	0.13 ± 0.14	-0.03 ± 0.00	
Soil × Distance	60.33	4.20	1.00	0.43	0.61	0.15 ± 0.15	-0.03 ± 0.01	0.00 ± 0.01
Null	89.78	33.66	1.00					
Soil	91.66	35.53	1.00	0.03	0.21	0.10 ± 0.13		
δ15N								
Soil × Distance	*229.95*	*0.00*	*0.95*	*0.51*	*0.77*	*-0.52 ± 0.43*	*-0.11 ± 0.01*	*0.06 ± 0.02*
Distance	236.55	6.60	0.99	0.44	0.70		-0.08 ± 0.01	
Soil + Distance	238.97	9.02	1.00	0.45	0.70	-0.12 ± 0.40	-0.08 ± 0.01	
Null	282.45	52.50	1.00					
Soil	284.30	54.34	1.00	0.04	0.36	-0.30 ± 0.41		
Phosphorus (%)								
Soil × Distance	-87.04	0.00	0.99	0.47	0.75	-0.24 ± 0.31	0.02 ± 0.01	-0.04 ± 0.01
Soil	-76.10	10.94	1.00	0.38	0.68	-0.55 ± 0.31		
Null	-75.98	11.06	1.00					

Soil + Distance	-73.69	13.34	1.00	0.38	0.68	-0.55 ± 0.31	0.00 ± 0.01	
Distance	-73.68	13.36	1.00	0.00	0.56		0.00 ± 0.01	
N:P Ratio								
Soil × Distance	209.64	0.00	0.86	0.41	0.71	0.34 ± 0.38	-0.05 ± 0.01	0.04 ± 0.01
Distance	214.60	4.96	0.94	0.09	0.59		-0.03 ± 0.01	
Soil + Distance	214.85	5.21	1.00	0.36	0.67	0.62 ± 0.01	-0.03 ± 0.00	
Null	225.74	16.10	1.00					
Soil	226.21	16.57	1.00	0.23	0.57	0.55 ± 0.37		
Sodium (mg/kg)								
Soil + Distance	*839.97*	*0.00*	*0.60*	*0.62*	*0.78*	*-0.99 ± 0.32*	*-0.03 ± 0.01*	
Soil × Distance	*841.56*	*1.59*	*0.88*	*0.62*	*0.79*	*-0.88 ± 0.34*	*-0.03 ± 0.01*	*-0.02 ± 0.01*
Distance	843.18	3.21	1.00	0.09	0.64		-0.03 ± 0.01	
Soil	852.98	13.02	1.00	0.53	0.71	-1.00 ± 0.32		
Null	856.49	16.52	1.00					
Magnesium (mg/kg)								
Soil × Distance	*722.20*	*0.00*	*0.99*	*0.45*	*0.80*	*-0.20 ± 0.28*	*0.00 ± 0.00*	*-0.02 ± 0.01*
Distance	731.74	9.54	0.99	0.07	0.66		-0.01 ± 0.00	
Soil + Distance	732.78	10.58	1.00	0.39	0.76	-0.36 ± 0.28	-0.01 ± 0.00	
Null	743.56	21.36	1.00					
Soil	744.46	22.26	1.00	0.31	0.69	-0.37 ± 0.28		
Potassium (mg/kg)								
Distance	*936.99*	*0.00*	*0.73*	*0.20*	*0.57*		*-0.03 ± 0.00*	
Soil + Distance	939.50	2.51	0.94	0.20	0.57	0.02 ± 0.25	-0.03 ± 0.00	
Soil × Distance	941.96	4.97	1.00	0.20	0.57	0.05 ± 0.26	-0.02 ± 0.01	0.00 ± 0.01
Null	956.55	19.57	1.00					
Soil	958.95	21.96	1.00	0.00	0.38	0.00 ± 0.24		
Calcium (mg/kg)								
Null	*799.64*	*0.00*	*0.42*					
Distance	*800.68*	*1.04*	*0.67*	*0.01*	*0.50*		*0.00 ± 0.00*	
Soil	*801.22*	*1.58*	*0.86*	*0.14*	*0.53*	*-0.20 ± 0.21*		
Soil + Distance	802.36	2.72	0.96	0.14	0.54	-0.20 ± 0.21	0.00 ± 0.00	
Soil × Distance	804.45	4.81	1.00	0.15	0.54	-0.16 ± 0.22	0.01 ± 0.01	-0.01 ± 0.01
Iron (mg/kg)								
Distance	*591.87*	*0.00*	*0.69*	*0.21*	*0.57*		*-0.08 ± 0.01*	

Soil + Distance	594.14	2.27	0.92	0.23	0.58	-0.26 ± 0.50	-0.08 ± 0.01	
Soil × Distance	596.15	4.27	1.00	0.23	0.59	-0.09 ± 0.39	-0.07 ± 0.00	-0.02 ± 0.02
Null	616.95	25.08	1.00					
Soil	619.06	27.19	1.00	0.02	0.48	-0.31 ± 0.00		

Table S3. Generalized linear mixed model results testing for correlations between leaf and soil micronutrients. The same model was run for each of five micronutrients (Na, K, Ca, Mg, and Fe) with leaf micronutrient concentration as the response variable, soil micronutrient + distance as the main effects, and site as a random effect. Marginal R^2 is the proportion of variance explained by both fixed and random effects in a model, and conditional R^2 is the proportion of variance explained by fixed effects. Coefficients (± standard error) are shown for each predictor and model.

Leaf Micronutrient	Mar. R^2	Con. R^2	Soil Micronutrient Coefficient ± *SE*	Distance Coefficient ± *SE*
Sodium	0.08	0.82	11.56 ± 11.67	-146.47 ± 43.04
Potassium	0.29	0.73	0.00 ± 0.00	-0.06 ± 0.01
Calcium	0.12	0.58	0.00 ± 0.00	0.00 ± 0.00
Magnesium	0.17	0.79	0.00 ± 0.00	0.00 ± 0.00
Iron	0.11	0.32	0.00 ± 0.01	-52.85 ± 20.57

Revised Supplemental Figures

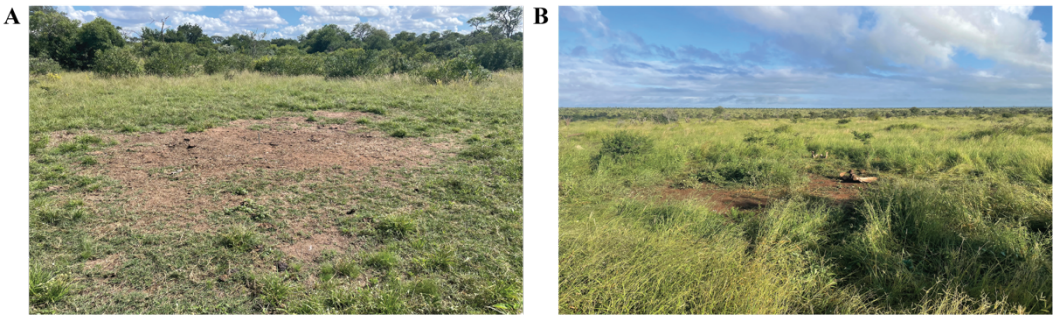


Figure S1. Representative photos of two elephant carcass sites of different ages and soil types. (A) The first site is 67 days post-death and is on granitic soil. (B) The second site is 811 days post-death and is on basaltic soil. In both images, there is a visible impact zone with reduced vegetation coverage. At the first site, elephant bones have all been dispersed, though some are still present at the second site. Photos taken by Deron Burkepile at time of sample collection in March 2023.

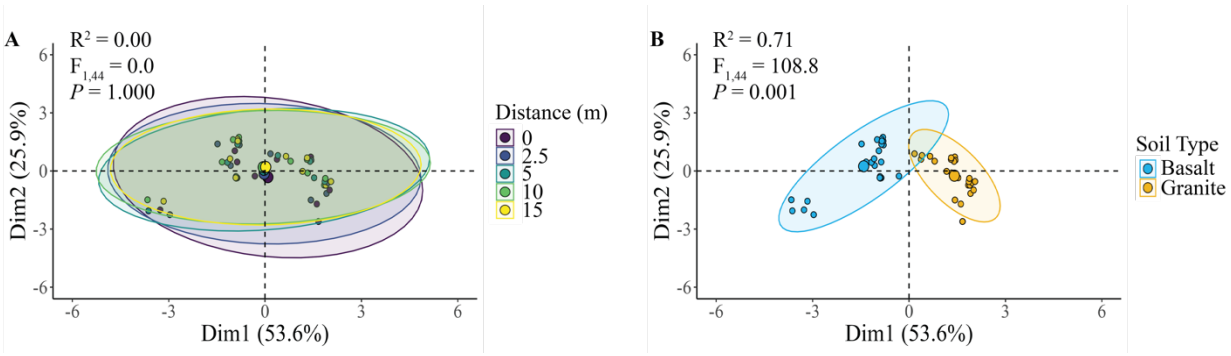


Figure S2. (A) Soil micronutrient composition did not differ significantly with distance from the carcass but (B) was distinct in different soil types.

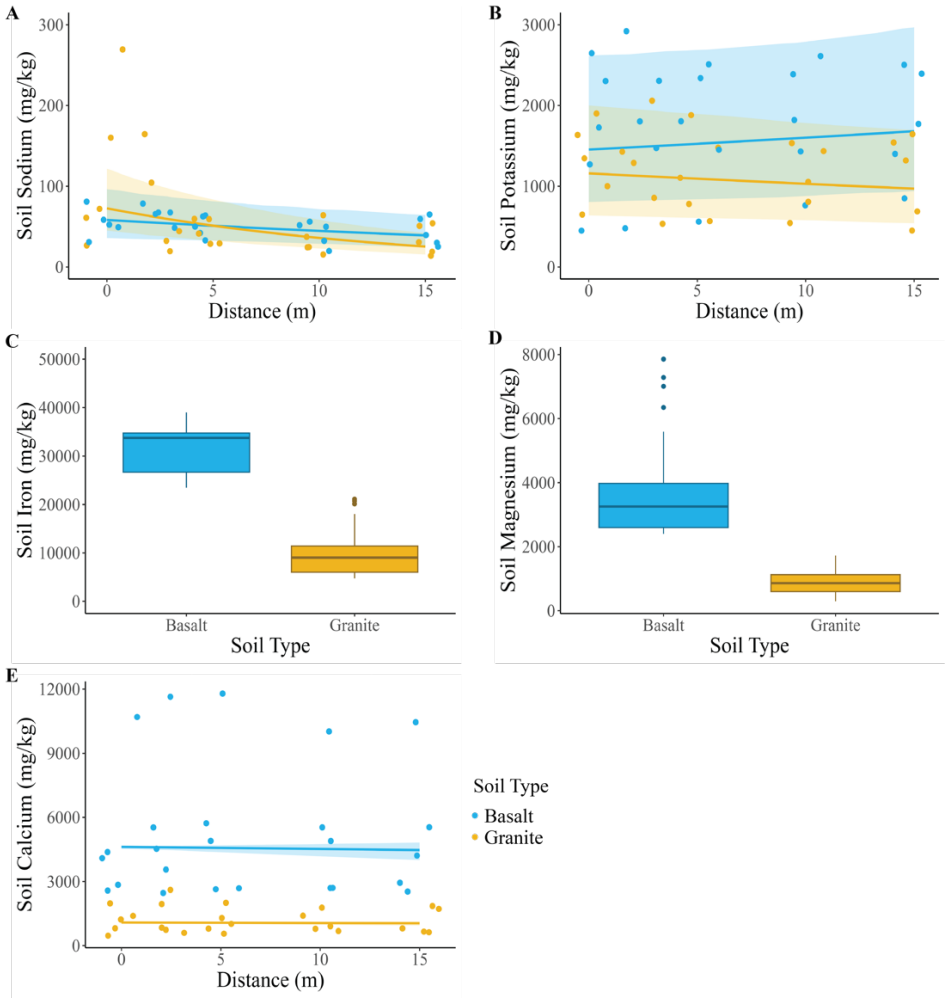


Figure S3. Effects of elephant carcasses on soil micronutrients. (A) Soil sodium decreased significantly with distance from the carcass. (B) Potassium decreased with distance but only in granitic soils. (C) Iron, (D) magnesium, and (E) calcium were greater in basaltic soils. Distance appeared in the top model for calcium, but the effect size was minimal. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap. Lines show predictions calculated from the top model. Shading indicates the 95% confidence interval.

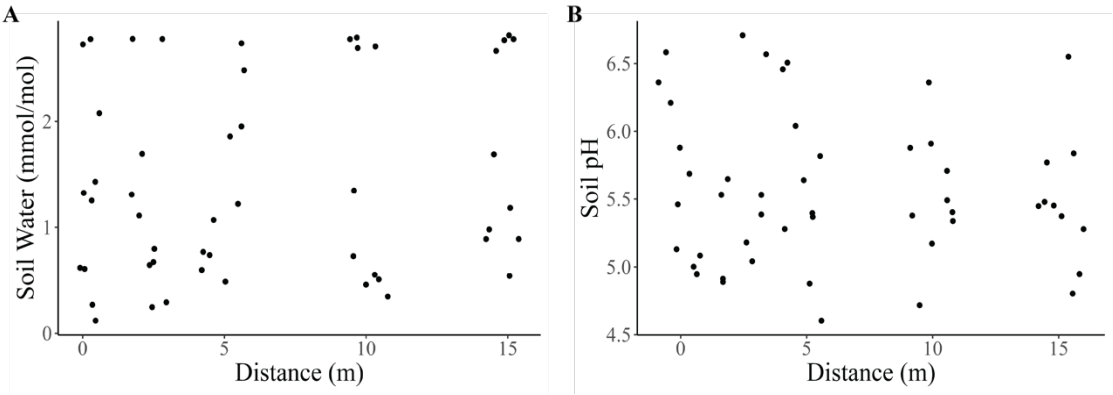


Figure S4. Neither (A) soil water nor (B) soil pH differed with distance or soil type. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap.

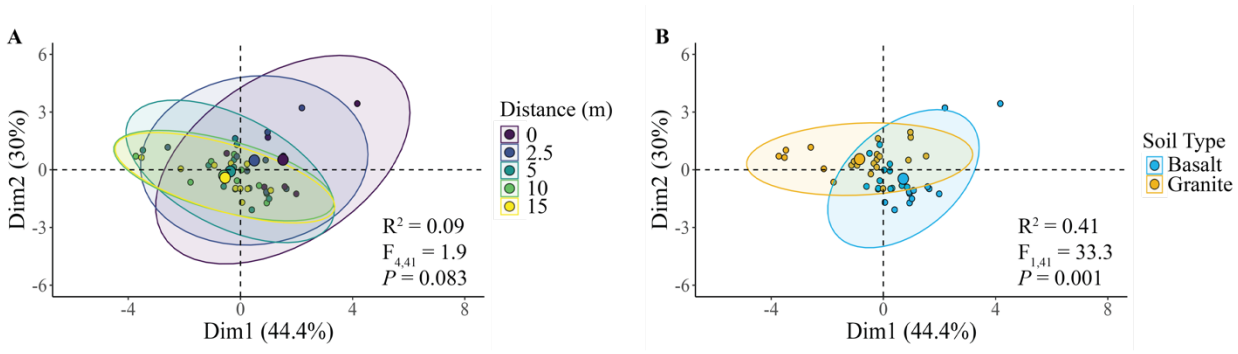


Figure S5. (A) Foliar micronutrient composition did not differ significantly with distance from the carcass but (B) was distinct in different soil types.

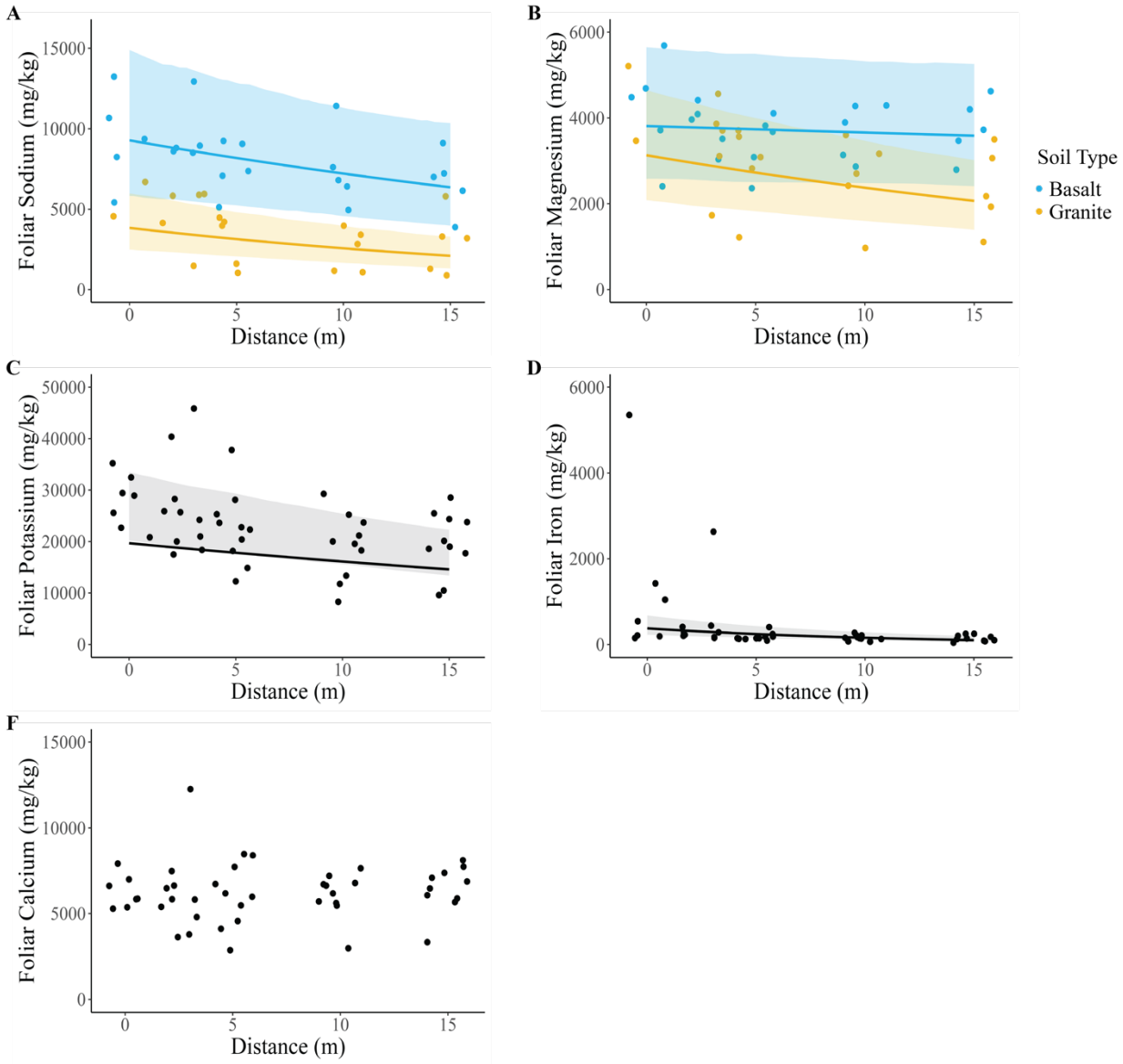


Figure S6. Effects of elephant carcasses on grass foliar micronutrients. (A) Foliar Na and (B) Mg were greatest in basaltic soil and decreased significantly with distance. (C) Foliar K and (D) Fe decreased with distance but did not differ with soil type. (E) Foliar Ca did not differ with distance or soil type. Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap. Lines show predictions calculated from the top model. Shading indicates the 95% confidence interval.