EFFECTS OF REFORESTATION ON MAMMAL COMMUNITIES, VEGETATION DYNAMICS AND CARBON STORAGE IN AFROMONTANE RAINFORESTS IN TANZANIA

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INTRODUCTION:

The global recognition of tropical forests' significance for biodiversity and ecosystem services underscores the urgency of understanding the impacts of reforestation and ecological restoration initiatives on vegetation dynamics, animal communities, and carbon storage. Despite this recognition, empirical evidence and data-supported insights into the efficacy of such projects remain scarce. However, the recent surge in reforestation and restoration efforts has created a unique opportunity to systematically collect data over the long term, presenting an unprecedented chance to deepen our understanding of these processes.

In this context, there is the potential to: i) monitor and analyze the colonization patterns of newly restored areas by animal species reliant on forest habitats, and their trends in adjacent forest reserves ii) conduct comprehensive studies on vegetation dynamics both within project areas and in adjacent forested areas such as Forest or Nature Reserves, and (iii) quantify the carbon storage capacity of reforested and restored lands. By taking advantage of this opportunity, we have the potential to greatly enhance our understanding of the intricate connections between land conservation, restoration initiatives, ecological processes, and carbon storage.

Our research aims to address these critical questions by comparing lands undergoing reforestation and restoration efforts with ecologically intact neighboring forests in the Udzungwa, Nguu, Nguru and Rubeho Mountains. Situated within the Eastern Arc Mountains of Tanzania, these mountain blocks are renowned for their exceptional biodiversity and ecological significance. Through rigorous scientific inquiry, we seek to test the hypothesis that reforestation and restoration projects facilitate the resurgence of forest-dependent species within the project areas and adjoining regions, consequently enhancing carbon sequestration capacities. Indeed, earlier studies conducted in the Udzungwa Mountains and other locations have revealed that poaching has led to a notable alteration in forest composition. Specifically, it resulted in a shift from forests primarily characterized by large tree species dispersed by animals to forests where smaller tree species, dispersed abiotically, dominate. By deploying robust methodologies encompassing ecological surveys, remote sensing techniques, and carbon accounting methodologies, we intend to generate comprehensive datasets to evaluate the effectiveness of reforestation and restoration initiatives. Through meticulous data analysis and interpretation, we aspire to discern the impacts of these interventions on biodiversity conservation and climate change mitigation efforts. Furthermore, our research endeavors to inform evidence-based conservation and land management strategies by providing empirical insights into the outcomes of reforestation and restoration projects. By elucidating the mechanisms driving changes in vegetation structure, species composition, and carbon dynamics, we aim to offer practical recommendations for optimizing the effectiveness of future restoration endeavors.

In summary, our study represents a concerted effort to bridge the gap between theoretical understanding and on-the-ground realities regarding the outcomes of reforestation and ecological restoration initiatives. Through collaborative interdisciplinary research and long-term monitoring efforts, we aspire to contribute meaningfully to the local and global conservation discourse and advance our collective efforts towards safeguarding biodiversity and mitigating climate change impacts in tropical forest ecosystems.

PROBLEM STATEMENT:

Despite the widespread recognition of the vital role tropical forests play in supporting biodiversity and ecosystem services, there remains a notable gap in empirical, data-backed scientific literature demonstrating the positive impacts of reforestation and restoration projects on vegetation dynamics, animal communities, and carbon storage. While the importance of such initiatives is widely acknowledged, the evidence supporting their efficacy remains limited, leaving a significant knowledge deficit in understanding their true impacts. A study by Chazdon et al. (2016) highlights the lack of comprehensive, long-term data on the outcomes of tropical reforestation efforts, emphasizing the need for sustained monitoring to assess ecological trajectories accurately. Similarly, recent research by Barlow et al. (2016) underscores the challenges in quantifying the effectiveness of restoration projects in enhancing biodiversity and carbon sequestration, particularly in tropical regions characterized by high species diversity and complex ecological dynamics. The complexity of tropical ecosystems, combined with the diverse array of factors affecting their recovery after reforestation, is a primary contributor to the scarcity of data-supported literature on the subject. Tropical forests comprise intricate networks of species interactions, where the success of restoration initiatives depends on factors such as seed dispersal, soil quality, and habitat connectivity (Crouzeilles et al., 2017). Consequently, accurately assessing the outcomes of reforestation efforts necessitates long-term monitoring efforts spanning decades to capture the full spectrum of ecological changes (Holl et al., 2019). Moreover, the efficacy of reforestation and restoration projects in restoring biodiversity and ecosystem functions may vary depending on the specific context, including site characteristics, historical land use, and management practices (Strassburg et al., 2019). This variability complicates efforts to generalize findings across different regions and underscores the importance of context-specific research to inform evidence-based conservation strategies (Melito et al., 2020). Furthermore, the lack of standardized methodologies for assessing the outcomes of restoration projects hinders efforts to compare results across studies and draw robust conclusions (Crouzeilles et al., 2017). Variations in monitoring protocols, study designs, and metrics used to evaluate success further contribute to the inconsistency in reported outcomes, limiting the synthesis of findings into actionable recommendations for policymakers and practitioners (Strassburg et al., 2019). Additionally, funding constraints and logistical challenges often impede long-term monitoring efforts, leading to gaps in data continuity and hindering the ability to track ecosystem recovery trajectories accurately (Chazdon et al., 2016). As a result, many restoration initiatives lack the necessary scientific rigor and empirical evidence to substantiate claims of success, perpetuating scepticism regarding their effectiveness among stakeholders (Holl et al., 2019). In conclusion, while the global imperative to restore tropical forests is undeniable, the dearth of data-backed scientific literature on the outcomes of reforestation and restoration projects hampers our ability to assess their true impacts on vegetation dynamics, animal communities, and carbon storage. Addressing this knowledge gap requires sustained investment in long-term monitoring efforts, standardized methodologies, and context-specific research to generate robust empirical evidence and inform evidence-based conservation practices in tropical forest ecosystems.

OBJECTIVE AND SIGNIFICANCE OF THE RESEARCH:

The primary objective of our research is to establish a comprehensive framework for studying the long-term impacts of reforestation projects on: i) mammal communities, ii) vegetation dynamics, and iii) carbon sequestration over the next three decades. By deploying rigorous methodologies and leveraging cutting-edge techniques, we aim to elucidate the complex interactions between reforestation efforts and ecosystem processes in tropical forest ecosystems. Through sustained monitoring and data collection, we seek to unravel the mechanisms driving changes in biodiversity, vegetation structure, and carbon storage dynamics following reforestation initiatives. Ultimately, our research endeavours to provide valuable insights into the effectiveness of reforestation projects in promoting ecological resilience and mitigating climate change impacts, thereby informing evidence-based conservation strategies and fostering sustainable land management practices in tropical regions.

HYPOTHESIS AND PREDICTIONS:

Our hypothesis suggests that the implementation of reforestation and ecological restoration initiatives will foster the expansion of forest-dependent species populations in project zones and adjacent regions, thus bolstering carbon sequestration capabilities. Specifically, we predict that as reforestation efforts progress and forest cover is restored, there will be a corresponding rise in species richness and abundance, particularly among those reliant on forest habitats for survival. This increase in biodiversity is expected to enhance ecosystem resilience and functioning, fostering greater carbon sequestration potential within reforested landscapes. Furthermore, we anticipate observing spatial variations in the responses of animal communities and vegetation dynamics across the study forests, corresponding to gradients of decreasing hunting pressure and increasing forest cover. Specifically, we predict that areas with lower hunting pressure and higher levels of forest cover will exhibit greater biodiversity and more rapid vegetation recovery post-reforestation. Additionally, we hypothesize that certain functional groups of species, such as those with specific trophic guilds or body sizes, may respond differently to reforestation efforts, influencing the composition and structure of animal communities. By testing these hypotheses and predictions through comprehensive field surveys, data analysis, and modelling approaches, we aim to advance our understanding of the complex interactions between land protection, restoration activities, ecological dynamics, and carbon sequestration in tropical forest ecosystems.

Our findings will be disseminated through peer-reviewed scientific papers, offering comprehensive insights into the dynamics of reforestation initiatives and their ecological implications. However, our primary focus will be on developing a set of guidelines tailored to assist other reforestation projects in the area. These guidelines will distil our research outcomes into practical recommendations and best practices, facilitating the implementation of more effective and impactful reforestation efforts. By sharing our findings in this manner, we aim to empower local stakeholders, policymakers, and practitioners with the knowledge and tools necessary to maximize the success of future reforestation endeavours in the region. A narrative report will be also produced and presented to the relevant authorities: Tanzania Forest Service and Village Natural Resource Committees.

METHODS:

To maximize variability and comprehensively capture the spectrum of reforestation outcomes, our research will encompass data collection from a diverse array of reforestation projects. In particular, our study will include collaboration with Udzungwa Corridor Ltd, the Nguru Reforestation Project run by PAMS foundation, and Village Climate Solutions. These initiatives represent distinct contexts within the tropical forest landscape, each with unique ecological characteristics, management strategies, and socio-economic factors influencing their outcomes. By engaging with multiple projects, we aim to obtain a holistic understanding of reforestation dynamics and identify common trends, challenges, and success factors that can inform more effective reforestation practices in Tanzania and neighboring countries. Furthermore, each of these projects spans a duration of 30 years or more, presenting a rare opportunity to gather and analyze data over several decades.

(1) Assessment of mammalian communities: data will be collected with camera-traps using TEAM's protocol for terrestrial vertebrates diversity (TEAM Network 2011), which consists of deploying minimum 30 camera trap sites (on average one every 2 square kilometres) for 30 days in the dry season (July-November; Rovero et al. 2014 for details). We will analyse data using state-of-the-art, 'multi-species and multi-region community modelling' (MRCM, Sutherland et al. 2016, Tenan et al. 2017). MRCMs are extensions of multispecies occupancy models (Dorazio et al. 2006) to study geographic variation in the size and functional composition of communities. Occupancy is the probability of presence of a species at a site and it is estimated correcting for detection probability, i.e. the likelihood that a species is detected given it is present. We will analyse camera trapping data to estimate richness and composition of target communities in relation to fundamental species' traits such as trophic guild and body size. Most importantly, we will test hypotheses on variation of these communities between the study forests in relation to decreasing hunting pressure, increasing forest cover and other potential drivers of change.

(2) Vegetation assessment: We will first sample the arboreal vegetation forest following the TEAM's vegetation protocol (TEAM Network 2010). Sampling consists of establishing 1-ha plots across a representative span of closed forest elevation range, within which all trees, lianas and tree ferns of 10cm diameter at breast height (i.e. 1.3 m above the ground) are measured and identified to species. Measurements are taken with plastic calipers and cloth diameter tape, each tree is marked with Aluminum tags and given a univocal code. We will use the help of a local expert botanist for species identification and a reference herbarium already made for the TEAM site. Trees of uncertain identification in the field will be sampled and later identified with help from Dr. Neduvoto Mollel, from the National Herbarium of Tanzania and Dr. Quentin Luke of the East Africa Herbarium (Kenya) who have extensive experience in the field and in the regional floras.

(3) Analyses of the effects of animal communities on vegetation dynamics: Tree plot data will be analyzed for parameters of forest structures (basal area, steam density and above-ground-mass), floristic composition (species richness and diversity) and species' functional traits, following Osuri et al. (2016). We will study seedling communities in both the protected and un-protected forests, following Condit (1998) and Effiom et al. (2013) that developed standardized methodology. Thus, we will sample two 25 square (5m x 5m) meters sub-plots in each 1ha plot, through the following procedures: -All plants with true leaves equal to 1 meter tall or less will be recorded, identified and sampled if necessary. -All 24 plots will be located randomly in deep shade. -Both tree and seedling species will be classified according to dispersal mode into two different groups, based on local expert knowledge and Osuri et al. (2016)'s trait database: (i) dispersed primarily by animals, and (ii) dispersed abiotically. Seedling data will then be analyzed for density, number of species per plot, dispersal mode, and size of seed using regression modeling (Effiom et al. 2013, Bolker et al. 2009).

(4) Analyses of carbon sequestration will involve conducting comprehensive carbon inventories within reforested areas and adjacent intact forests, following established protocols outlined by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2019). Carbon stocks will be measured across various components, including above-ground biomass, below-ground biomass, litter, and soil organic carbon, utilizing field sampling techniques and laboratory analysis (Pan et al., 2011). Additionally, remote sensing techniques such as Light Detection and Ranging (LiDAR) or aerial imagery will be employed to estimate forest canopy structure and biomass at landscape scales (Asner et al., 2010). Changes in carbon stocks over time will be assessed through repeated inventories and remote sensing analyses (Lu et al., 2018). Subsequently, carbon sequestration rates will be calculated, taking into account factors such as tree growth rates, species composition, and land management practices, to evaluate the contribution of reforestation projects to mitigating atmospheric carbon dioxide levels (Houghton et al., 2015).

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