Final Evaluation Report

Your Details	
Full Name	Oscar Rafael Lanuza
Project Title	Assessment of the actual and potential Carbon stock of tropical forest fragments in the protected landscape of Miraflor-Moropotente in northwest Nicaragua
Application ID	32146-1
Date of this Report	May 2023

1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Set up of 40 long-term forest monitoring plots			x	
Tree species checklist for the protected landscape of Miraflor-Moropotente (MMPL)			x	We have generated an official list of tree species with their scientific name confirmed by The Plant List, and we have verified their status on the IUCN red list.
Analysis of the community structure and conservation status of MMPL forests			x	The ecological analysis of the plots will be completed in April 2024. Currently, a preliminary analysis of the diversity of the forests in the protected area has been carried out. Thanks to the support of this project, Carmen Albir, a student of Environmental Engineering at the National Autonomous University of Nicaragua, carried out her final degree project entitled Taxonomic and functional diversity of remnants of tropical forests of the Miraflor-Moropotente protected terrestrial landscape.
Estimation of current and projected carbon storage capacity of MMPL forests			x	We completed the calculation of the above-ground carbon stock (AGC) and of the organic carbon present in the topsoil. We are currently validating the allometric and statistical models used in these estimations. With the results of the AGC, we are preparing a carbon map for the protected area that will be

				very valuable for the forest management of the protected area.
Submission of two manuscripts to international peer-reviewed academic journals		x		We are currently writing two manuscripts arising from the data gathered thanks to The Rufford Foundation funding. We expect to submit them during the second semester of 2023. Currently, another related article is under peer-review. This separate paper deals with soil carbon sequestration capacity through biochar addition during the implementation of the forest restoration programmes of the study area.
Workshops with key stakeholders providing management and policy recommendations		x		Regular feedback has been done informally with all key stakeholders and landowners. A proper workshop is planned once the carbon estimates and analysis of the diversity of the plots are completed. This should be done by the second semester of 2023.
Workshops with local primary schools within the MMPL to increase nature awareness			x	The workshops with primary school students in the MMPL were held in April 2023.

2. Describe the three most important outcomes of your project.

a). The set up of 40 long-term forest monitoring plots and the tree species checklist for the MMPL.
This project constitutes a great advance for the knowledge of the diversity of the remnants of tropical forests that persist in the protected area. It is important to mention that the network of temporary plots in the protected area should be expanded, to cover other forest formations such as secondary forests and therefore better understand the ecosystem.

b). The analysis of the community structure and conservation status of MMPL forests

In 40 plots of 0.25 ha, 4762 trees >= 10 cm dbh belonging to 238 species of 158 genera corresponding to 70 botanical families were identified. Of the 238 species found, five are endemic to Nicaragua and 12 are threatened with extinction on the IUCN Red List. A preliminary analysis of gamma diversity using Hill numbers shows that the effective number of species (${}_0D$), common species (${}_1D$) and dominant species (${}_2D$) were significantly higher in the riparian forest and transition forest, intermediate in the tropical dry forest and cloud forest, and the pine-oak forest has the lowest diversity. Thus, the riparian and transition forests, are of vital importance as refugees of tree species diversity and may serve as natural germplasm bank to promote future ecological restoration projects.

c). The estimation of current and projected carbon storage capacity of MMPL forests.

This was the central goal of the research in this project. Accordingly, we have generated new wood density data for more than 70 so far unrecorded plant species. We have done so applying standardised protocols for measuring functional traits. For the rest of the species, data was available at www.try-db.org and after applying nine allometric equations, we were able to estimate the carbon stock of the for each type of forest. The above-ground carbon stock (AGC Mg C/ha) was higher in riparian forest, cloud forest and transition forest (235.04, 224.4 and 144.0 Mg/ha, respectively), while tropical dry forests and pine-oak woodlands had the lowest stocks (57.1 and 78.5 mg/ha, respectively). Hence, the AGC of the cloud forest was approximately 4 times higher than that of the tropical dry forest.

To have a more precise vision of the carbon stock of the protected area, we also estimated the organic carbon stock of the soil. To achieve this, we carried out a soil sampling and a complete elementary analysis of the soil of the 40 plots up to a depth of 30 cm. The apparent density of the soil of each plot was calculated with a 90.47 cm^3 cylinder at a depth between 0-15 cm. Soil organic carbon stock (SOC Mg/ha) = H × BD × OC × 10 where H is soil depth (cm); BD, bulk density (g/cm^3); OC, organic carbon concentration in the bulk soil (g/kg).

To take full advantage of the forest inventory data and of the knowledge gathered for each plot, we performed full elementary analyses for 167 forest species present in the area and that did not have published data on their functional traits in the www.try-db.org. Of these species, new information on their leaf area, specific leaf area, leaf dry matter content was also generated. This new information will be used to prepare another article on functional and phylogenetic diversity of tropical forests of north Nicaragua.

3. Explain any unforeseen difficulties that arose during the project and how these were tackled.

One of the main difficulties in this study was the time invested in inventorying each plot, the initially estimated time per plot was very little compared to the real time needed once in the field. The high diversity of tree species and the difficulty of their identification in situ, very challenging even for our specialised plant taxonomist, as well as the adverse climatic conditions of the area, specially during the wet season, were the main factors that increased the field stage.

Another unforeseen event was the access to the area since the roads that led to the plots were severely affected by rain, which made access difficult, so the sampling lasted much longer than expected.

During the project we also had some negative side effects of the COVID-19 pandemic, which made some administrative procedures and the purchase of materials more difficult than usual. Another associated difficulty was that some forest owners did not allow access to their properties or were new owners who were little known in the protected area.

In all these situations, the only way to deal with these unexpected drags was to re-schedule activities, invest more time in the field and also giving more time to land-owners to properly understand our purposes and thereby dissipate doubts about our activities in they properties.

4. Describe the involvement of local communities and how they have benefitted from the project.

Forest owners grant permission to repeatedly visit the plots to conduct forest inventories, as well as to collect wood, leaf, and soil cores from the plots. The owners of the plots with empirical knowledge about the identity of the forest species supported by providing some local common names of the forest species, which were later corroborated by Aldo Marcel Velasquez (the field technician and specialised plant taxonomist in our team) and Oscar Lanuza (the principal investigator). The owners of the plots will eventually receive a list of the forest species present in their forests and their actual and potential carbon storage capacity. This will allow them to have a better understanding of forest species and the importance that these forests have in sequestering carbon. Additionally, the Government of Nicaragua has plans to calculate their national carbon storage capacity through their national institute of forestry and the ministry of natural resources and eventually participate in international carbon markets. The landowners that have collaborated with this project will be able to certify their service in carbon sequestration and

conservation and will be able to join any scheme of paying-for-ecosystem-services or similar initiative that can eventually arise in the future.

5. Are there any plans to continue this work?

The information generated with this project is extremely valuable for the conservation of the protected area, for this reason, I consider that the immediate route to continue this work can be:

Firstly, submission of the two manuscripts to international peer-reviewed academic journals with the main results, one on carbon estimates of aerial and soil biomass, and the other article on the functional diversity of forest species that make up these forests.

Secondly, once the article on functional diversity has been published, the data on functional traits generated in this study will also be published in a digital repository with its respective form of citation.

Thirdly, to transform all the technical information generated into more accessible information for all audiences, such as children and non-specialist personnel on the subject.

Fourthly, the elaboration of a unique and updated map of the carbon stock of the protected area is foreseen, which will serve to guide the local conservation policies of the protected area.

Finally, the set of long-term forest plots funded by the RSG will be permanently monitored in the future. To achieve so, we have got additional funding, and we are seeking for additional sources in order to keep our field samplings in the MMPL, thus increasing our knowledge on forest dynamics and biodiversity components.

6. How do you plan to share the results of your work with others?

The accomplishment of the academic output of the present project will be easily checked by means of the production of the two scientific papers. This will allow us to share our work with specialised audiences.

For lay people in the MMPL area, we will conduct workshops with local primary schools within the MMPL to present the key results of the project to increase nature awareness.

Finally, we will conduct workshops with key stakeholders providing management and policy recommendations (i.e. local communities and their agricultural cooperatives, private landowners, NGOs and practitioners of public institutions).

7. Looking ahead, what do you feel are the important next steps?

The conversion of forest areas to other land uses increasing forested area and the connectivity between forest patches at a landscape level is a crucial step if we are to tackle climate change effects at a local and global scale. Therefore, stopping deforestation and increasing forest areas is a challenge of paramount importance. which eventually will also help to reverse the current biodiversity loss crisis. To intensify the impact of this project, we have sought new funding to continue monitoring our plots and also to expand the number of plots to the less representative vegetation types present in the protected area to maximise our understanding of how these forests function and respond to global change.

On the other hand, we have got additional funding to implement a large-scale forest conservation and restoration project with the purpose of increasing connectivity between forest patches and the forest cover of the protected area, while focusing on increasing the regeneration capacity of several target tree species that are threatened according to IUCN's Red List. Finally, another strategical line we are developing is to generate new inter-institutional alliances between our university with public administrations and private associations of farmers and landowners to improve existing conservation efforts and create new opportunities for intervention in the area.

8. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

The logo of the foundation was used for the presentation during the workshops with children from primary schools within the protected area. The logo was also used to make educational posters. The foundation received additional publicity by means the Twitter handles of @oscarlanuza6 and @Guille_Peguero, both members of our team. In this social network, we have been regularly sharing the progress of our project, such as the difficulties experienced during the field inventories, especially in the riparian forests.

9. Provide a full list of all the members of your team and their role in the project.

MSc. Oscar Lanuza has been a tenured professor at UNAN Managua since 2012. He has a master's degree in management and conservation of tropical forests and biodiversity from the Tropical Agricultural Research and Higher Education Center

CATIE, Costa Rica. He is a PhD student in Terrestrial Ecology at the Autonomous University of Barcelona (UAB). Oscar's role in this project was being the principal investigator, he designed the idea together with Dr. Guille Peguero. Along with Mr. Aldo Velásquez, he managed the relationships with local land-owners, he selected the the plots, carried out the forest inventories, the soil sampling and the functional traits of the stems and leaves. Oscar carried out the filling and curation of the databases and led the analysis of the data and the writing of the manuscripts.

Mr. Aldo Marcel Velásquez Olivas is a plant taxonomy specialist with a long practical experience in biodiversity eco-tourism and mountain hiking for floristic interpretation in the MMPL area. He has participated in forest inventories of natural forests in teak producing farms with the company Equiforest Inc. In addition, he has also taken part in forest inventories with the local NGO FUNDAR, outsourced by ERM consulting, to carry out a series of environmental impact studies for the construction of the interoceanic canal through Nicaragua. The role of Aldo in this project was field technician and taxonomist, in charge of the botanical identification of the species found in the field. He participated in the delimitation of the plots, the forest inventory, the sampling of stem and leaf functional traits, as well as in the filling of databases and environmental education workshops with the children. Additionally, he leveraged his long-term acquaintances in the area to engage local communities and landowners with the project.

Dr. Guille Peguero is a lecturer at the University of Barcelona (Spain). He carried out his PhD in forest ecology at the Miraflor-Moropotente area. His research focus on the interplay between biodiversity in its different dimensions with ecosystem functioning. He is also the supervisor of the PhD of Mr. Oscar Lanuza. In this project, the role of Dr. Peguero has been a key advisor for the design and installation of the forest plots, the supervision of the statistical analyses and the writing of the resulting scientific papers.

Prof. Dr. Josep Peñuelas is the principal investigator of the Global Ecology Unit (CSIC-CREAF, Spain) and PhD supervisor of the Mr. Oscar Lanuza. He is one of the most influential and respected ecologists at a global level. His research is focused on the effects of global change on the biosphere. Prof. Peñuelas has been advisor in this project, particularly during the analysis and writing of the results obtained from the investigation.

10. Any other comments?

We are very grateful to The Rufford Foundation for the funding received. We want to stress that even small amounts of funding such as the RSG programme can really make a difference in countries like Nicaragua where is particularly challenging to have access to international sources of funding and thus to promote nature conservation and increase the basic knowledge of our ecosystems. This RSG project

is a seed that will provide the basis for a long-term forest inventory programme that we will work to replicate at a larger scale throughout Nicaragua.