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Assessing the potential of Integrating payment for ecosystem services through Carbon Credit Trading in the Sebeya Catchment: A Case Study of Nyabirasi afforestation area, Rutsiro District-Rwanda

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I. INTRODUCTION

1.1. Research Background

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- Payment for Ecosystem Services (PES) is a market-driven conservation approach that incentivizes sustainable environmental practices (Wunder, 2005).
- Carbon Credit Trading is an emerging mechanism for monetizing carbon sequestration benefits, contributing to climate change mitigation (Pagiola et al., 2002).
- The Sebeya Catchment, characterized by deforestation and land degradation, presents an opportunity for PES implementation to enhance afforestation efforts (Nsabimana et al., 2010).
- Studies indicate that afforestation projects can significantly improve carbon sequestration rates and support rural livelihoods (Smith et al., 2013).
- This study assesses the feasibility of integrating PES through Carbon Credit Trading in the Nyabirasi Afforestation Area, analyzing environmental and economic benefits.

1.2. PROBLEM STATEMENT

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- Despite global recognition of PES as a tool for environmental sustainability, its implementation remains limited in many developing regions, including Rwanda (Ferraro & Kiss, 2002).
- Deforestation and land degradation in the Sebeya Catchment threaten ecosystem services, yet existing conservation efforts lack sustainable financing mechanisms (Karsenty et al., 2017).
- Community participation in afforestation initiatives is often low due to limited awareness and financial incentives (Pattanayak et al., 2010).
- Carbon Credit Trading has been identified as a potential solution, but its feasibility, economic benefits, and impact on local livelihoods remain underexplored in the Nyabirasi area (Jack et al., 2008).T
- This study seeks to bridge these gaps by assessing the potential integration of PES through Carbon Credit Trading and evaluating its environmental and socio-economic implications.

1.3. RESEARCH OBJECTIVES

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- **General Objective**

To assess the potential of integrating Payment for Ecosystem Services (PES) through Carbon Credit Trading in the Sebeya Catchment, focusing on the Nyabirasi Afforestation Area, and its implications for environmental sustainability and community livelihoods.

- **Specific Objectives**

❑ To estimate the current and potential carbon sequestration rates within the Nyabirasi Afforestation Area to determine its contribution to mitigating climate change.

❑ To examine the economic feasibility and potential benefits of integrating PES through Carbon Credit Trading and its contribution to local livelihoods.

❑ To provide recommendations and guidelines for scaling up the integration of PES and Carbon Credit Trading in similar contexts.

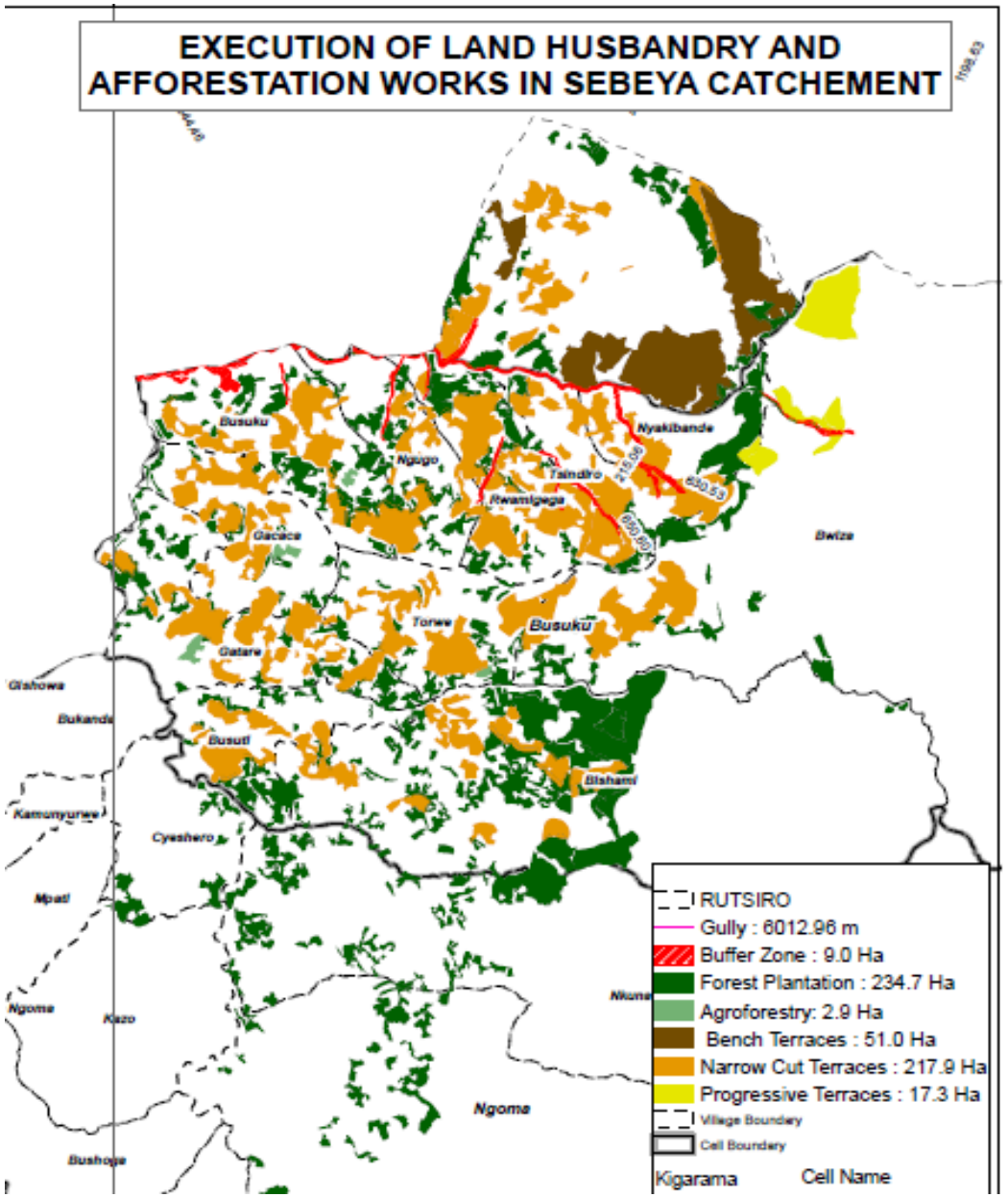

Figure: The Nyabirasi Afforestation Area (234.7 Ha)

3.1 Study Area

- **Location:** The study is conducted in the Nyabirasi Afforestation Area, within the Sebeya Catchment in Rutsiro District, Western Rwanda.
- **Geographical Features:** The Sebeya Catchment is characterized by steep slopes, high rainfall, and significant land degradation due to deforestation and poor agricultural practices.

3.2 Literature Review

- Different species of trees present different capacities for sequestering carbon (Hou et al., 2020).
- Biodiversity and ecosystem conservation efforts continue to dwindle while negatively impacting the environment and causing climate change effects, (Mesa-Sierra et al., 2022).
- Payment for Ecosystem Services has recently become a global trend to enhance environmental sustainability, (Le et al., 2024).
- Since studied in the early 1990s, payment for Ecosystem services has been viewed as positive for both environment and people's livelihood, (Suich et al., 2017)

3.2. STUDY DESIGN

- The study employed **a quantitative research methodology.**
- It is descriptive research, with data collection methods including:
  - **Primary Data:** Household surveys, structured interviews with key stakeholders (farmers, local authorities, environmental experts)
  - **Secondary Data:** Review of existing literature, Reports from Rwanda Water Board, Reports on carbon sequestration, and PES-related policies.
- The study utilized a **stratified simple random sampling** to ensure a diverse representation of community members and stakeholders.
- Research Analysis:
  - **Quantitative Analysis:** Statistical tools such as Paired T-Tests, and Regression analysis.

IV. RESULTS AND DISCUSSION

4.1. Estimation of the current and potential carbon sequestration rates within the Nyabirasi Afforestation Area to determine its contribution to mitigating climate change.

SN	Planted Trees	Total
1	Alnus acuminata	32,574
2	Grevillea robusta	27,257
3	Chrysophyllum gorongosalum (umutoyi)	750
4	Hagenia abyssinica	4,572
5	Macaranga kilimandscharica (umusekera)	2,778
6	Acacia abyssinica (umunyinya)	3,762
7	Croton megalocarpus	16,226
8	Erythrina abyssinica (umuko)	3,928
9	Anthocleista grandiflora (umwarangabo)	2,220
10	Neoboutonia macrocalyx (umwanya)	2,358
11	Polyscias fulva (umwungo)	18,861
12	Podocarpus falcatus and latifolius (umufu)	20,282
13	Maesopsis eminii (umuhumuro)	16,337
14	Entandrophragma excelsum (umuyove)	20,844
15	Prunus africana (umwumba)	5,209
16	Albizia gummifera (umusebeya)	1,872
17	Kigelia africana (umuvungavungo)	1,570
18	Carapa grandiflora (umushwati)	7,889
19	Syzygium guineense (umugote)	5,957
20	Markhamia lutea (umusave)	3,800
21	Dombeya goetzenii (umukore)	4,435
22	Persea americana (avoka)	42,768
23	Myrianthus holstii (Umwufe)	7,078

Table: Data from Rwanda Water Board

- **Average Carbon Sequestration Rate:** Different tree species sequester carbon at different rates. (Hou et al., 2020).
- To estimate the current and potential carbon sequestration rates within the Nyabirasi Afforestation Area, the study used **standard carbon sequestration factors** for the planted tree species. The general approach included:

  - **Estimating Above-Ground Biomass (AGB):** Using biomass expansion factors for each species.
  - **Calculating Below-Ground Biomass (BGB):** Applying root-to-shoot ratios.
  - **Determining Carbon Stock:** Assuming carbon constitutes ~50% of total biomass.
  - **Estimating Carbon Dioxide Equivalent (CO_2e) Sequestration:** Using a conversion factor of 3.67 (ratio of molecular weights of CO_2 to C).

4.2. ESTIMATED CARBON SEQUESTRATION RATES (CURRENT & POTENTIAL)

Tree Species	Total Trees	AGB per Tree (kg)	BGB per Tree (kg)	Total Biomass (kg)	Carbon Stock (kg C)	CO_2e Sequestration (kg CO_2e)
Alnus acuminata	32,574	75	18	3,042,102	1,521,051	5,579,460
Grevillea robusta	27,257	90	22	3,051,253	1,525,627	5,596,050
Chrysophyllum gorongosalum	750	80	20	75,000	37,500	137,625
Hagenia abyssinica	4,572	85	21	487,884	243,942	894,262
Macaranga kilimandscharica	2,778	60	15	208,350	104,175	381,341
Acacia abyssinica	3,762	70	18	330,996	165,498	605,366
Croton megalocarpus	16,226	95	24	1,932,212	966,106	3,544,161
Erythrina abyssinica	3,928	88	22	432,512	216,256	793,696
Polyscias fulva	18,861	72	19	1,716,247	858,124	3,147,328
Podocarpus falcatus	20,282	100	25	2,531,692	1,265,846	4,648,856
Maesopsis eminii	16,337	92	23	1,918,487	959,243	3,520,412
Prunus africana	5,209	80	20	520,900	260,450	955,852
Albizia gummifera	1,872	78	19	181,776	90,888	333,558
Markhamia lutea	3,800	85	21	403,000	201,500	738,505
Persea americana	42,768	60	15	3,207,600	1,603,800	5,871,946
Myrianthus holstii	7,078	77	19	678,326	339,163	1,243,781

Table: Calculations in line with planted trees and sequestered carbon

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- **Total Carbon Sequestration Potential:**
- **High Carbon Sequestration Capacity**
  - The total estimated carbon stock is **~9,137,065 kg C.**
  - The total CO_2 sequestration potential is **~33,483,338 kg CO_2e.**
  - This confirms that the afforestation area plays a crucial role in offsetting greenhouse gas emissions.

4.3. EXAMINING THE ECONOMIC FEASIBILITY AND POTENTIAL BENEFITS OF INTEGRATING PES THROUGH CARBON CREDIT TRADING AND ITS CONTRIBUTION TO LOCAL LIVELIHOODS.

- **To assess the economic potential and livelihood improvement, the study utilized the following:**
  - **The Cost Benefit Analysis** to evaluate the economic feasibility
  - **Analysis of the Household income impact** to measure livelihood benefits before and after the project introduction in the area through Survey
  - **Hypothesis (Paired T-Test**) to statistically validate the hypothesis
- **Cost Benefits Analysis:**
  - **Carbon Credit Price:** 15$ per metric ton of **CO_2e**
  - **Potential Sequestration:** 33,483,338 kg
  - **Total Revenue from Nyabirasi Afforestation: (33,483,338/1000)*15= 502250.07 USD**
- **Project Expenses: 420,000 USD as of Sept. 2024**
  - Calculations of Net Benefits:
  - **Net Benefits** = Total income-Total Expense= 502,250.07-42,6500= 75,750.07 USD annually

As the Net Benefit is positive, the PES project was deemed beneficial.

- Analysis of the Household income impact The Cost Benefit Analysis to evaluate the economic feasibility
  - 50 Households in Nyabirasi have been surveyed. They participate in the Project through different types of work
  - The Average income before the project was around **50 USD/**Month
  - The Average income after the project has been enacted is ~~around **65 USD**/Month~~
  - **Income Change= $\frac{\text{(After } \bar{x}\text{- Before } \bar{x})*100}{50}$**
  - Income Change= $\frac{(65- 50)*100}{50}$ =**30%**

The surveyed population reported an increase of 30% after participating in the project. The Project is viable and contributes to livelihood development.

4.4. HYPOTHESIS (PAIRED T-TEST) TO STATISTICALLY VALIDATE THE NULL HYPOTHESIS

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Null Hypothesis (H_0):
Integrating PES through Carbon Credit Trading is not economically feasible and does not provide significant benefits to local livelihoods

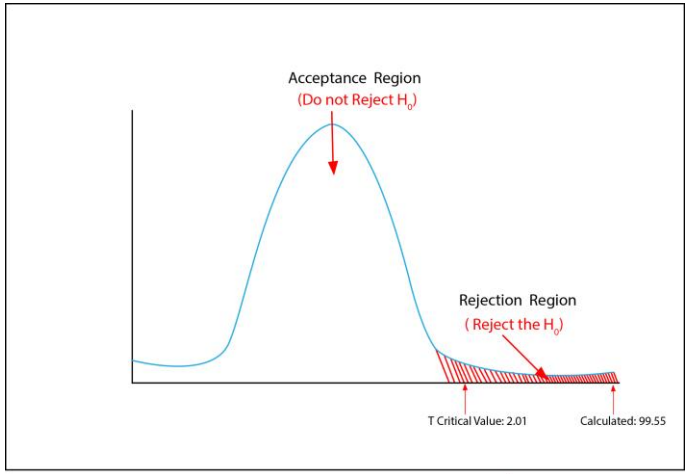
A survey of 50 workers' monthly payment

Income Before Nyabirasi Afforestation Project									
50	52	48	49	51	50	53	47	49	50
48	51	49	50	47	52	50	51	49	50
48	50	51	49	47	52	50	50	48	51
50	49	50	52	50	50	51	50	48	49
50	47	51	50	48	50	49	50	48	51

Income After Nyabirasi Afforestation Project									
65	67	63	64	66	65	68	62	64	65
63	66	64	65	62	67	65	66	64	65
63	65	66	64	62	67	65	65	63	66
65	64	65	67	65	65	66	63	64	65
62	66	65	63	65	64	65	63	66	67

Xd (Mean difference)= Income after- income before

- $\bar{x}d = \frac{(752)}{50} = -13.1$
- $\bar{x}d = -15.04$
- Sd = STDEV.S(C2:C51) = 1.068281091
- Because the sample mean is positive, the study used a right-tail T-Test
- Significance Level: 0.05



The **Null Hypothesis (H_0)** has been rejected. There is enough evidence that the Nyabirasi Afforestation project contributed to livelihood improvement by integrating PES through CCT.

- **Tcv (T critical Value)= 2.01**
- **Tc (T calculated)**
- $Tc = \frac{\bar{x}d - M_d}{Sd/\sqrt{n}} = \frac{15.04-0}{1.068/\sqrt{50}} = 99.55$

Verdict: Tc > T critical Value

- The Calculated T statistics at 99.55 provide extremely strong evidence to reject the null Hypothesis.

- ***Note:***

The Calculated T Statistic looks inflated beyond the usual number of -3 and 3. This is because there is a high mean difference before and after the project implementation. Further, the number of surveyed population (50) also contributed to the high T calculated and the low standard deviation.

V. RECOMMENDATIONS

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- This research recommends Government agencies, the Private Sector, and NGOs be extensively involved in Integrating payment for ecosystem services through Carbon Credit Trading activities specifically in the Sebeya Catchment. The Nyabirasi Afforestation Project has contributed so much in mitigating climate change and enhancing the livelihood of the local population so it has to be continuously strengthened.

- Involve the population in the project activities as much as possible to ensure the sustainability of the project

- Increase Forest management practices with a priority on local populations' training and mobilization of a specialized technical team to assist them in the implementation of forest conservation measures.

- This research recommends further studies to assess various factors affecting the involved population. This was a quantitative Study, there is a need for qualitative or mixed studies to collect the perception of the local population on the project and how their awareness contributes to the project's effectiveness.

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Thank You

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