Estimating Environmental & Biodiversity Costs of Oil Pipeline Development in Murchison Falls National Park, Uganda

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Photo: Lukas Maverick Greyson

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1. INTRODUCTION

Commercially viable quantities of oil and gas resources have been discovered in the Albertine Rift region of Uganda. This is estimated to yield up to 6.5 billion barrels of oil. Some of this discovery lies in the biodiversity hotspot of Murchison Falls National Park (MFNP), which contributes to national development as it is a major source of tourism revenue and offers other ecological benefits of immense value. The country plans to construct a pipeline to evacuate the oil from the national park to the Central Processing Facility (CPF) in Buliisa district. Construction of this pipeline has potential to negatively impact the ecosystem and biodiversity of the national park. These costs are often ignored in project design and implementation as frequently developers consider them external to the project. This study identifies and estimates the otherwise less emphasized environmental and biodiversity costs (compared to economic benefits) with respect to pipeline infrastructure development in MFNP. Also, it shows methodologies that can be used to incorporate these costs into the definition of pipeline routes and to guide other mitigation measures.

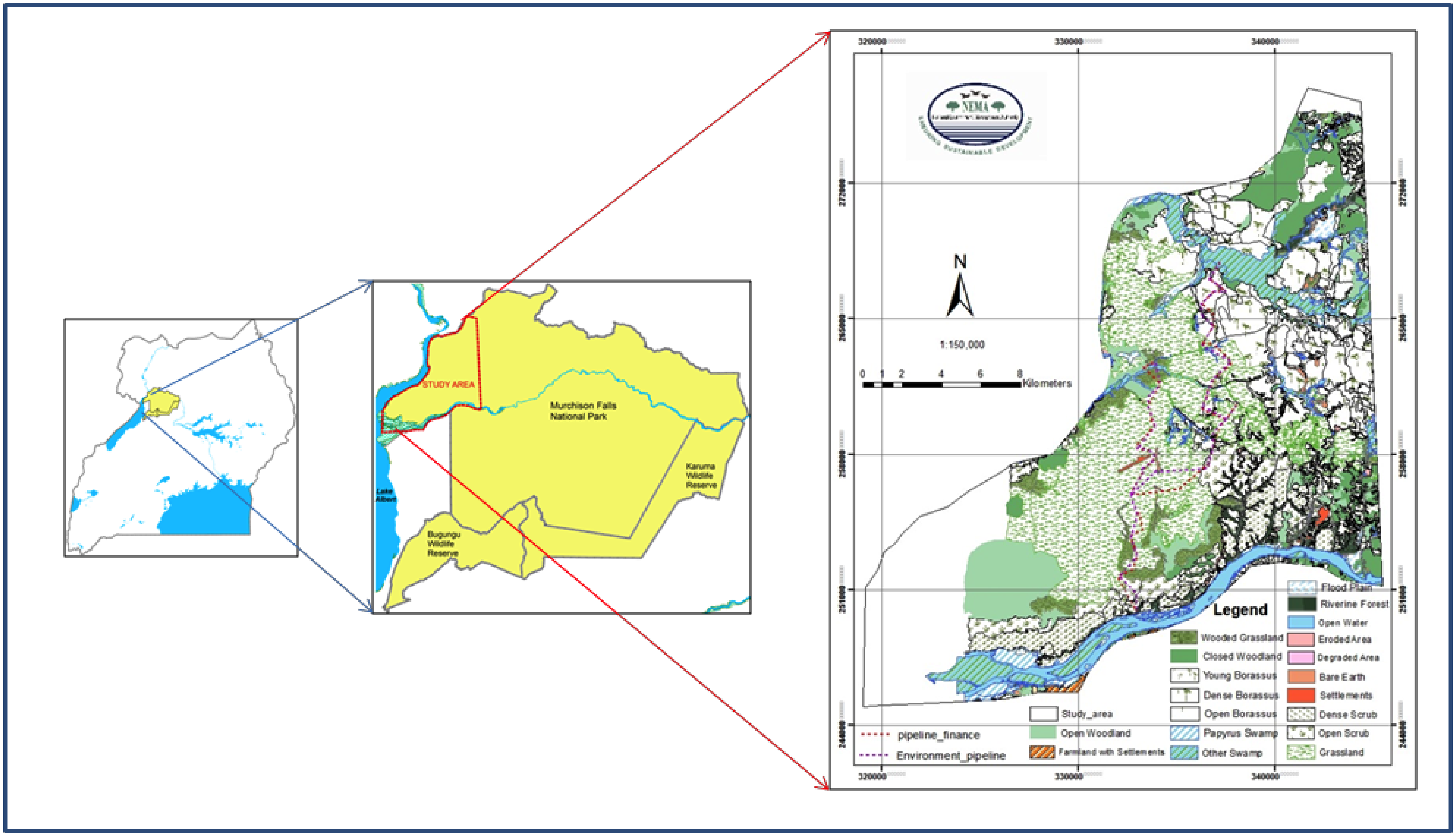
2. APPROACH

The study included five major steps. First, we identified the features that would influence the financial cost of the pipeline, and the main environmental features that would be affected by pipeline development (Figure 1). These features were weighted at a stakeholders' workshop comprising of national and international experts in environment, and oil and gas developments, including oil companies operating in Uganda. The list was later subjected to further international scrutiny through submitting to various international experts familiar with oil and gas development requirements who advised on how to adjust the weights. The output of this process provided the weights for each feature (refer to Annex 1), which was the basis for identifying avoidance areas (areas with high environmental & financial cost) and assessing potential impacts of pipeline options.

The second step involved the generation of a single map with the identified features, referred to as the resistance layer, which was used in the identification of the potential routes for the pipeline. To show how the different environmental aspects identified would be affected when varied efforts of environment conservation were considered, two scenarios were developed. The Financial Cost Saving Scenario prioritized the financial aspects; in this scenario features that determined the financial cost of the pipelines were assigned a total of 70% weight and the environmental aspects 30%. The Environmental and Biodiversity Conservation Scenario prioritized environmental and biodiversity features, thus financial aspects were given a 30% weight and environmental aspects 70%. Least Cost Path (LCP) analysis was used to generate the potential pipeline routes for both scenarios. This type of analysis identifies the path with the lowest cost/resistance between two points[1]: the higher the cost, the higher the resistance value of the cell on the map.

[1] Selection of the start and end points used in the modeling of the LCP was guided by the location of the furthest oil and gas well in the north and the lowermost point in the south of the study area. Two middle points/sites, within the oil and gas exploration wells' distribution area, were also selected to restrain the pipeline from being located very far from where oil and gas resources have been discovered.

Figure 1: Study area and key features identified



The third step was to assess pipeline development impacts in terms of areas that would be impacted by the pipeline development. Three impact levels were considered: 1) the Right of Way (ROW) where there will be direct impacts through alteration or complete removal of vegetation cover and sub-soils; 2) a one kilometer buffer from ROW; and 3) a three kilometer buffer from ROW, where there will be a mixture of direct and indirect impacts of varied levels (including: soil erosion, trampling of soils by the large number of workers, introduction of nona native species and increases in poaching due to increased access to remote areas within the park). Other potential impacts, that go beyond the areas analysed, are: atmospheric and water pollution, increase in solid waste generation and deposition inside the protected area due to poor disposal habits of workers, impacts to wildlife (especially disturbance of animal movement, distribution and feeding habits), and damage to the overall park's scenic beauty.

The fourth step was to calculate the economic value of the environmental impacts of the impacts within the ROW. This as pipeline construction in this area will result in loss of vegetation cover and habitat, as well as temporary displacement of wildlife. The value of ecosystem services lost was estimated using the Benefit Transfer method, considering direct damage along the pipeline right of way, and making an estimate of the duration of impact, i.e., until vegetation can recover and wildlife presumably return. Two sources of information were used. For most Environmental Services (ES), we use average values for grassland biomes from the TEEB database (de Groot et al., 2012), which represents a global effort to collect all high quality valuation studies. Although studies are not all from directly comparable regions, we believe that use of an average value is suitably conservative given the global importance of Murchison Falls. For recreation and soil retention, we use values from NEMA (2013), who carried out primary studies of these themes among others for MFNP. We calculate the value of damages only under the environmental pipeline, as this is the scenario under which all reasonable avoidance of damage has presumably already been undertaken.

The final step was proposing specific mitigation measures based on the information analysed.

3. RESULTS

Two potential pipeline routes were modelled; one where financial cost saving was the priority and the other where environmental and biodiversity conservation were prioritized. Figures 2 and 3 show each of the scenarios' resistance layers and least cost paths.

Figure 2: Financial Cost Saving Scenario resistance layer and Least Cost Path (LCP)

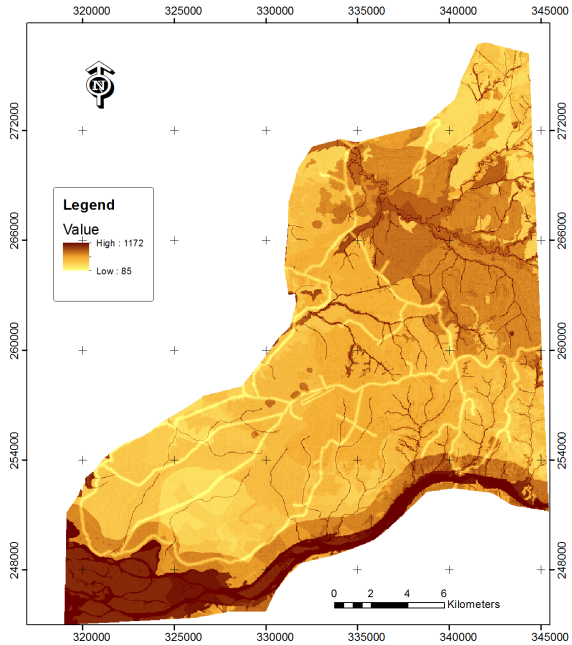


Plate 1: Resistance layer Financial Cost Saving Scenario

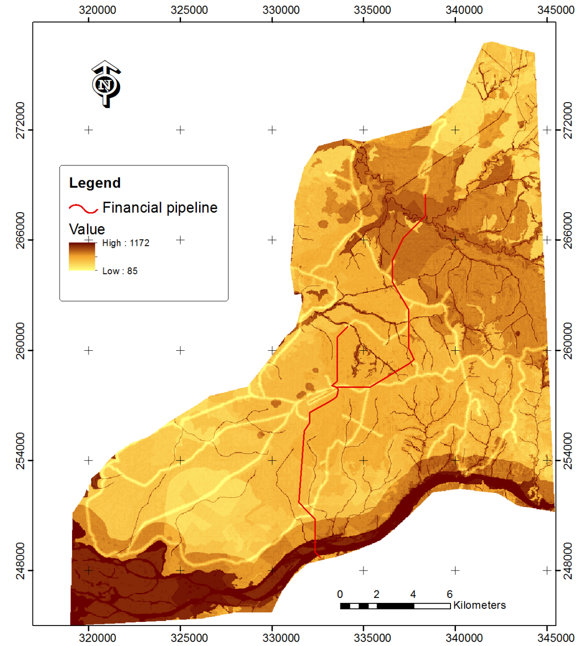


Plate 2: Least Cost Path Financial Cost Saving Scenario

Figure 3: Environmental Conservation Scenario Resistance layer and Least Cost Path (LCP)

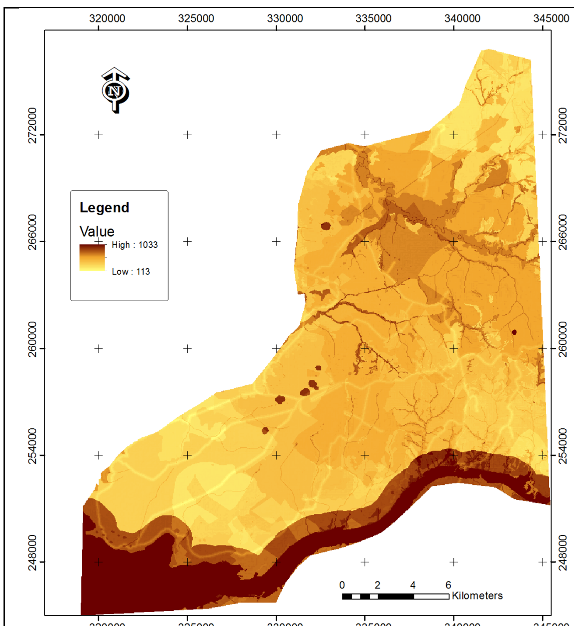


Plate 3: Resistance layer Environmental Conservation Scenario

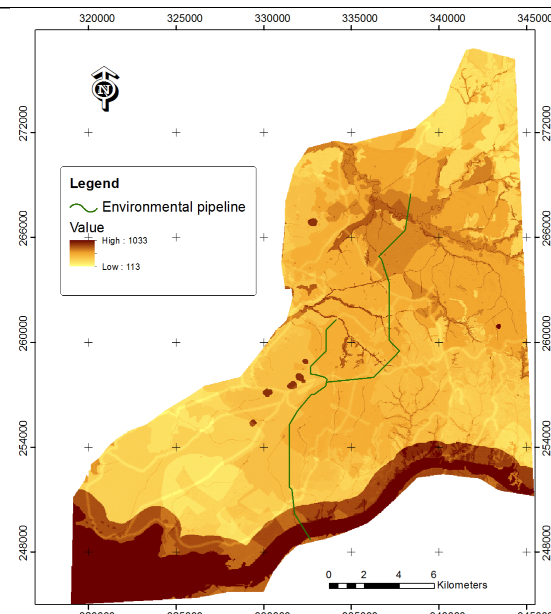


Plate 4: Least Cost Path Environmental Conservation Scenario

Comparison of the resistance layers for the two scenarios

In the Financial Cost Saving Scenario resistance layer, areas with water are the most costly to traverse, followed by woodland areas, and Ramsar areas. Within the woodland area, a narrow part that is a flood plain was also rated as high cost, whereas medium cost and least costs were assigned to the koblex[2], wallows[3], and road infrastructures. In the environmental resistance layer, open water, koblex, wallows and wetland were rated very high followed by areas of intersection of borassus and areas with important populations of large mammals. The lowest cost was assigned to existing infrastructure. Refer to Annex 1 for specific feature weights.

Comparison of the potential pipeline paths

Table 1: Financial and environmental scenario routes length & area under ROW

	Scenario 1: Financial Cost Saving Scenario	**Scenario 2: Environmental Conservation Scenario**
Length	30.6 KM	31.1 KM
Total Area	92.33 Ha	95.53 Ha

The pipeline prioritizing financial cost savings was shorter than the one prioritizing environmental conservation (Table 1). The financial pipeline crossed three wallows while the environmental pipeline crossed only one wallow. In the northern part, the environmental pipeline curved away from a low financial cost area (small light-coloured area near river) to avoid wallows occurring within that area. The financial pipeline, on the other hand, crossed through that low financial cost area and in the process went over the wallows. The koblex had a lower value in the financial resistance layer than in the environmental resistance layer but none of the pipelines crossed through any of them.

Land-take

To assess pipeline development impacts in terms of land take, we considered three impact levels, i.e. the ROW where there will be direct impact through alteration or complete removal of vegetation cover, a one kilometer buffer and a three kilometer buffer from ROW where there will be a mixture of direct and indirect impact of varied levels. For all three distances, total land take was greater for the Environmental Conservation pipeline than for the Financial Cost Saving pipeline route. Considering individual land cover classes, the greatest land-take for both potential pipeline routes for all buffers was in the grassland areas. Figure 4 shows land-take within the ROW; values of land-take for all buffers are shown in Annex 2.

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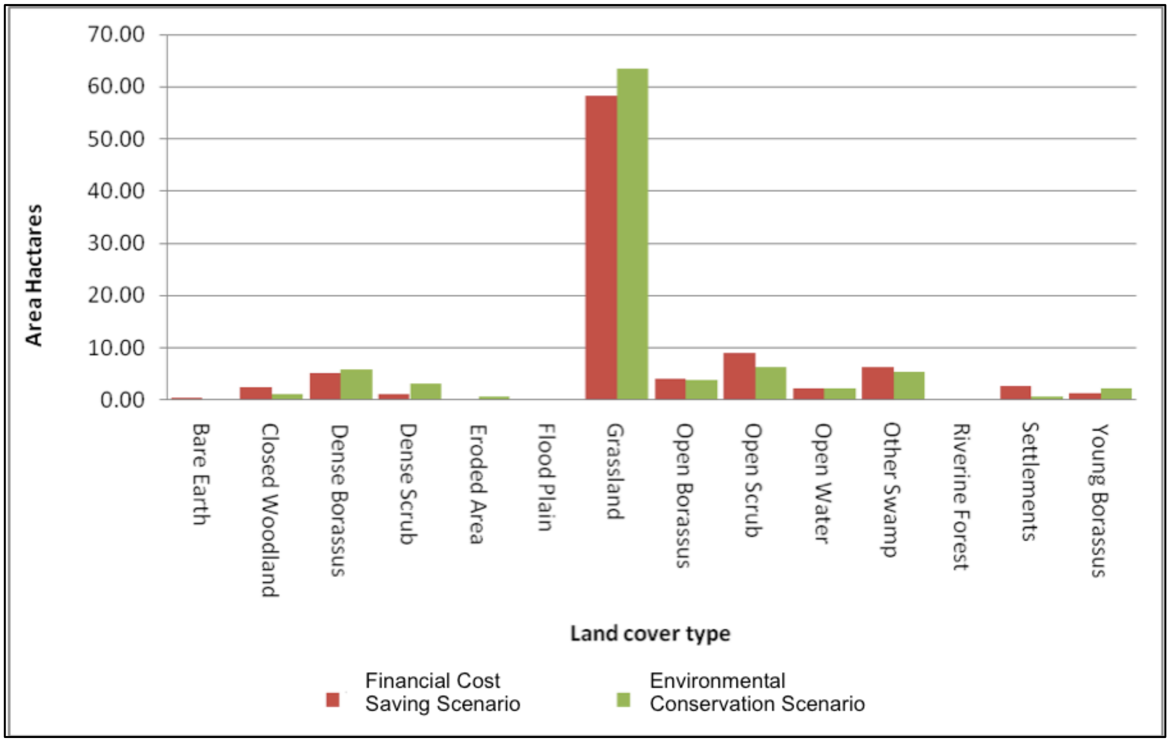
[2] Koblex – Permanent mating ground for Uganda Kobs within a specific territory. It is specially selected by Kobs based on unique desirable characteristics.

[3] Wallows – Seasonal or permanent ponds where wildlife, especially buffaloes and hippos, roll in the muddy clay water to control their body temperature, and to eliminate or protect themselves from biting insects like ticks.

Figure 4: Comparison of area land take with the Right of Way of the Financial Cost Saving (in red) and Environmental Conservation Scenario (in green) routes.



Evaluating actual area of land-take, it was evident that the pipeline taking environment conservation as a priority generally used less of the environmentally sensitive areas than the one prioritizing financial cost saving. In the one kilometre (1KM) buffer, the Environment Conservation pipeline covered only 0.64Ha of the flood plain, while the Financial Cost Saving pipeline covered 2.25Ha of that system. For the same buffer distance, the Environment Conservation pipeline also had less land-take for water, papyrus and other swamp, and riverine forest land cover types. For the 3KM buffer, the environment pipeline had much lower area for closed woodland, open borassus and other swamp. There are also trade-offs that can be observed e.g. in the 3KM buffer, whereas the grassland and wooded grassland areas of the Environment Conservation pipeline were greater than those taken by the Financial Cost Saving pipeline by 70.84Ha and 52.59Ha respectively, the financial pipeline had lower values in vegetation cover types that would be more expensive to traverse e.g. the closed woodland and open borassus by 33.53Ha and 40.2Ha respectively. It should, however, be noted that not only vegetation cover influenced the final value of any area. Other variables like animal population numbers from aerial surveys were also included.

The Environmental Conservation pipeline used more grassland and wooded grassland because they were assigned a lower value during the weighting due to their faster recovery from disturbance, and because they are often less diverse than the other land cover types that were being ranked. The grassland was, therefore, generally preferred as a pipeline route because it had one of the lowest resistance values and yet it covered a large part of the study area.

Economic value of the environmental impacts

Building on the TEEB database and NEMA (2013) reports, four main categories of ecosystem functions that can be attributed to natural ecosystems and their associated ecological structures and processes were valued. Table 2 indicates the replacement cost for the Environmental Scenario pipeline right of way. The habitat loss considered the general vegetation cover lost which is the home for wildlife and will lead to their temporary displacement and relocation.

Table 2: Environmental Scenario route´s ROW replacement costs

Ecosystem functions	Monetary value (US$/ha Year)	Duration minimum (years)	Area size affected (ha)	Total value of ecosystem services (US$)
Regulating services				
Climate change	40	5	95.53	19,106
Disturbance regulation	NA	5	19.11	-
Water regulation	60	5	95.53	28,659
Soil retention	122	2	47.77	11,656
Biological control/Pollination	NA		0.00	
Supporting services				
Loss of habitat/Shrubs, trees, grass and herbs	NA	5	95.53	-
Refugium function/water wallows, salt licks, termite mounds	NA	2	4.78	-
Nursery/genetic diversity (seed bank)	1214	2	95.53	231,947
Soil formation	10	2	0.00	-
Nutrient cycling	21100	2	0.00	-
Provisioning services				
Food	1192	2	95.53	227,744
Raw materials – Grass, herbs, shrubs, others	53	2	73.97	7,841
Forest	84	5	13.16	5,712
Cultural services				
Aesthetic value	167	2	71.65	23,931
Recreation and tourism	195	5	71.65	69,877
Science and education	NA	NA	NA	NA
Total				**626,473**

The results indicate that the total estimated value of ecosystem services, which would be damaged as a result of the pipeline development under the environmental scenario, is US$626,473. These results assume that all ecosystem functions and biodiversity are replaceable within the time frame (2-10 years) used in the analysis, which is not necessarily the case. For the natural resources or ecosystem functions that may take longer than the indicated period to recover, additional costing may be required since they would have been under-costed in the first place. Furthermore, as noted, important services are not assigned a value, given lack of suitable work from which to carry out benefit transfer. Finally, for some services, such as tourism, the impact of the pipeline might much higher than that estimated on the basis of a per-hectare Benefit Transfer, because a pipeline would affect the value of this service beyond the ROW area.

Mitigation measures

Pipeline development has potential to cause a variety of impacts on the environment e.g. loss of wildlife habitat, reduction in fauna and flora diversity within the disturbed area, soil erosion increase, introduction of invasive species and loss of other ecosystem services. To avoid or minimize such impacts to biodiversity and ecosystem services, we recommend the following mitigation measures.

- To minimize land-take, habitat loss and soil erosion, the pipeline construction should be restricted to the 30 meter right of way, oil and gas extraction points should be consolidated to reduce the number of well pads, and use of appropriate technology such as using directional drilling to access oil from other wells should be considered. In addition, ensuring that oil companies restore cleared areas as soon as possible should be a priority.

- To minimize disturbance of animal feeding habits, behavior and ranging patterns, which often leads to human-wildlife conflict, the human footprint associated with the pipeline and other oil activities should be limited through controlling the number of workers allowed at a site and times of carrying out operations. In this case, operations should be restricted to daytime and use of floodlights at night should be limited. Effort should also be made to create alternative areas of environment conducive to wildlife, such as the creation of additional watering points outside the area of oil and gas operations.

- Equipment and personnel to respond to an oil spill should be in place at all times.

- Poaching should be minimized through establishment of workers' camps outside the protected area, increasing anti-poaching effort in the area and minimizing human traffic within the area of operation.

- Alternative tourism sites should be established and developed outside the operation area to mitigate the reduction in number of tourists and related revenue loss, and where necessary compensate for the lost revenue. To improve park-community relationship and livelihoods of communities in the oil and gas development area, employment of community members should be encouraged.

- To ensure the mitigation activities have the effects stipulated in the Environmental Impact Assessments, governments should require performance bonds.

- Establishment of an environment fund, specifically setup for restoration of the area at the end of the oil and gas extraction lifetime, should be secured prior to the authorization of construction.

- For those ecosystem services that are foreseen to be damaged as a result of the pipeline and oil and gas activities in general, despite adequate application of the mitigation measures described here, payment for environment and biodiversity offset should be secured in an environment fund prior to the authorization of construction of the pipeline.

4. Conclusion and recommendations

This paper showed how information on environmental features could be used during the planning stage of a project to optimize routing of linear infrastructure and estimate environmental costs within the project's right of way. Also, specific mitigation activities to ensure minimization of environmental damages were proposed.

The Environmental Conservation pipeline route identified avoided damage of ecologically sensitive features such as wallow, koblex, flood plains and vegetation cover important to wildlife survival by routing away from them, which resulted in a longer pipeline. Although the available data was adequate for modeling of the potential pipeline at a course scale, other data sets such as well-production sites and base rock would have enabled us to produce a more fine-tuned output. For micro routing of the pipeline, high-resolution data of all the variables will be required. The generated potential pipeline route was limited to the main pipelines. Auxiliary pipelines supplying the main pipeline were not considered due to limited information about location of main well pads and points of accessing oil and gas through directional drilling.

Natural resource valuation before a project is implemented can reveal important information about the value of the area to be affected and may influence a developer's decision to either implement a project within a specific location or relocate it to another because of cost implications. Developing infrastructure in ecologically sensitive areas, therefore, requires consideration of environmental cost at all stages of a project.

Based on the information analyzed we recommend:

i. Other environment factors that may influence pipeline location, e.g. geological data and planned location of well pads, were left out during this study ought to be identified and included in future identification of pipeline infrastructure.

ii. During the pipeline construction phase, effort should be made to ensure that wide-ranging animals are not restricted and inbreeding is avoided. This as the proposed pipeline literally cuts off an area with the highest congregation of wildlife.

iii. Pipeline routing incorporates environmental considerations to minimize biodiversity and environmental damages.

iv. All stages of infrastructure development within ecologically sensitive areas i.e. project planning, implementation and evaluation should estimate and incorporate project impacts on environmental values through the use and generation of environmental data and economic analysis tools.

v. Capacity building in the use and generation of environmental data and economic analysis tools.

vi. Careful assessment of tradeoffs arising from infrastructure project developments to guide the design and tailor appropriate mechanism to balance environmental, financial, economic and social considerations.

vii. Design of policy guidelines on development of informed biodiversity offsets arising from the infrastructure development.

viii. Design of financial mechanisms, such as mitigation performance bonds and offset environmental funds, during the project's planning stage and secured as a condition to project's approval.

ix. Further study as well as scaling up and replication of similar studies to other areas in Uganda should be considered a priority.

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Annex 1: Weights assigned to features according to stakeholders' workshop

Table A1: Table generated from the ranking activity and then calculated values for the two scenarios

Factor	Standardised values	Financial saving prioritization Scenario 1 (F70:E30)	Environmental conservation prioritization Scenario 2 (F30:E70)	Relative Weights for Financial only (100%)
Land cover		17.5	7.5	**25**
Large open water (Not rivers)	20			
Built up/towns	15			
Wetland	12			
Borasus palm	10			
Grassland & Bushland (Grazing)	5			
Farmland	10			
Forest/Plantation - timber	6			
Plantation - cash crop	5			
Wooded	2			
Grassland & Bushland (Barren)	5			
Rivers		17.5	7.5	**25**
Within river	15			
Not within river	0			
Slope		10.5	4.5	**15**
0-2 degrees	0			
2-6 degrees	2			
6-10 degrees	5			
10-20 degrees	10			
Greater than 20	15			
Faults		10.5	4.5	**15**
No faults	0			
Minor fault present	5			
Major fault present	20			
Roads		14.0	6.0	**20**
Road	5			
Highway	10			
1-25m from road	0			
25m-50m from road	5			
50m-100m from road	10			
Greater than 100m from road	15			
				Relative weights for Environmental only (100%)
Ramsar Site		7.5	17.5	**25.0**
Ramsar site	20			
Not ramsar site	0			
Environmental Importance of land cover (Plant and Bird Biodiversity)		6.0	14	**20.0**
Large open water (Not rivers)	20			
Wetland	12			
Borasus palm	10			
Grassland	5			
Forest	6			
Wooded & Bushland	2			
Environmentally Important area for mammals		6.0	14	**20.0**
Mammal distribution: 0.82 - 1.41	5			
Mammal distribution: 1.41 - 1.99	10			
Mammal distribution: > 2.0	15			
Koblex		7.5	17.5	**25.0**
No Koblex	0			
Koblex present	20			
Wallow		3.0	7	**10.0**
No wallow	0			
Wallow present	15			
Total		100.0	100.0	

Annex 2: Land-take per cover type

Table A2.1: The ROW area land-take per cover type for the Financial Cost Saving and Environmental Conservation Scenarios.

Cover type	**Financial Cost Saving Scenario Area (Ha)**	**Environmental Conservation Scenario Area (Ha)**
Bare Earth	0.29	0.23
Closed Woodland	2.29	1.17
Dense Borassus	4.98	5.85
Dense Scrub	1.10	3.24
Eroded Area	0.15	0.75
Flood Plain	0.00	0.00
Grassland	58.29	63.47
Open Borassus	4.01	3.85
Open Scrub	8.89	6.27
Open Water	2.19	2.27
Other Swamp	6.28	5.52
Riverine Forest	0.12	0.00
Settlements	2.56	0.61
Young Borassus	1.16	2.30
Grand Total	**92.33**	**95.53**

Table A2.2: 1KM area land-take per cover type for the Financial Cost Saving and Environmental Conservation Scenarios.

Class Name	**Financial Cost Saving Scenario Area (Ha)**	**Environmental Conservation Scenario Area (Ha)**
Bare Earth	14.23	14.26
Bushland	0.10	5.36
Closed Woodland	56.85	56.36
Dense Borassus	405.06	449.17
Dense Scrub	130.27	128.77
Eroded Area	29.19	28.20
Farmland	6.58	6.58
Flood Plain	2.25	0.64
Grassland	3548.98	3673.60
Open Borassus	371.40	369.47

Open Scrub	519.16	560.66
Open Water	145.96	143.48
Open Woodland	43.66	43.66
Other Swamp	480.02	455.58
Papyrus Swamp	11.61	9.04
Riverine Forest	15.08	10.51
Settlements	25.46	25.46
Wooded Grassland	198.16	171.48
Woodland	0.66	0.66
Young Borassus	56.63	56.63

Table A3.3: 3KM area land-take per cover type for the Financial Cost Saving and Environmental Conservation Scenarios.

Class Name	**Financial Cost Saving Scenario Area (Ha)**	**Environmental Conservation Scenario Area (Ha)**
Bare Earth	23.61	23.61
Bushland	5.48	5.48
Closed Woodland	366.31	332.78
Dense Borassus	1517.95	1525.77
Dense Scrub	518.57	508.58
Eroded Area	51.23	57.46
Farmland	10.87	10.84
Flood Plain	129.93	129.93
Grassland	8290.40	8361.24
Open Borassus	1589.59	1549.39
Open Scrub	1613.51	1618.76
Open Water	355.71	353.75
Open Woodland	481.39	488.44
Other Swamp	1429.46	1410.85
Papyrus Swamp	82.92	83.34
Riverine Forest	156.48	175.17
Settlements	25.46	25.46
Wetland	0.00	0.00
Wooded Grassland	843.39	895.98
Woodland	1.19	1.07
Young Borassus	56.63	56.63