**Gums for Adaptation and Mitigation in Sudan (GAMS):**

**Economic & Financial Analysis and Environmental Co-Benefits**

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## Introduction

1. The economic and financial analyses uses cost-benefit analysis for the GAMS project, while seeking to determine financial, economic and environmental co-benefits generated from investments in agroforestry systems. Main activities relate to agroforestry, reforestation and rangeland restoration across the three states of Sudan – North, South and West Kordofan. The land distribution is as in the table below.

### Table 1: Land usage under GAMS and coverage area (in ha)



1. The primary project beneficiaries are smallholder farmers (SHF) engaged in mixed agroforestry farming systems and pastoralists engaged in rearing of livestock. The project envisages improved co-management of natural resources for better climate adaptation and mitigation from improved management practices of forest, farming and pasture areas.

1. The EFA uses Cost-benefit Analysis (CBA) to determine whether the dollar benefits of the project are likely to outweigh dollar costs. The CBA monetizes major benefits and costs associated with the project, so that they can be directly compared with each other. The financial and economic analyses use regional models for North & West Kordofan and South Kordofan respectively[[1]](#footnote-2), to assess the financial and economic viability of agroforestry systems, reforestation activities and rangeland restoration, while investments in the potential reduction in GHG emissions are accounted for using the FAO EX-ACT tool. Quantified benefits from rangeland restoration include improved livestock nutrition, especially for cows, which leads to productivity increases, and GHG emissions decreases in absolute terms. The CBA compares the ‘with project’ to the ‘without project’ scenario over a 20-year timeframe, using a discount rate of 18 percent to reflect the average commercial lending rate in Sudan, and 10 percent for the social discount rate, used by the GCF for related investments. The analysis assumes an initial adoption rate of 100 percent of the target numbers, followed by drop-out rates of around 20 percent, thereby arriving at an adoption rate of round 80 percent[[2]](#footnote-3).
2. Given the challenging climate conditions and recurrent moisture stress suffered by crops (see Chapter 2 of Prefeasibility study), projections on yield assumes varying levels of output, swinging between extreme weather events (total crop failure), moderate years (60-80 percent output) and good years (100 percent output) of the defined average for the state. The frequency of such events differs between North and West Kordofan on the one hand and South Kordofan on the other as per the table below.

### Table 2: Frequency and extremity of weather events, by state



1. The investments under **Component 1: Restoration of smallholder gum agroforestry systems and improvement of gum value chain** constitute around 56 percent of total project funds, with an estimated USD 5.6 million of allocated funds for the agroforestry systems restoration and reforestation and smallholder gum producer group support, of which 100 percent comes from GCF funding. A significant portion of the GCF funding will go to financing direct field-level investments, with an estimated USD 2.53 million, under component 1. Investments in the densification of agroforestry and forestland areas along the gum arabic belt, livestock corridors and rangeland areas will result in a significant increase in carbon sequestration and ecosystem services, the latter contributing directly to climate change adaptation. Ecosystem services derived from investments include reduced wind speed, increased shading, improved water infiltration, reduced surface run-off, and subsequently reduced evapotranspiration, increased biomass, increased soil nutrient content, increased moisture retention through increased organic matter and increased crop yields. These services are accounted for by a slower decrease of the CARD tool rates of change over the discount period, at a rate of 3 percent per year. Additional off-site benefits exist, such as reduced damage to infrastructure from flooding, which are not quantified under the analysis. They result from improved water infiltration and reduced surface run-off.
2. In areas with reforestation activities planting density on bare land will shift from an approximate 10x10m format to a 4x5m or 6x3m layout, resulting in an additional 400 and 456 plus trees per hectare. In areas with agroforestry, the densification activities will result in a shift from 8x8m to 6x6m, or an additional 122 trees per ha, intercropped with field crops over a 15-year period and then left fallow over the remaining 5 years. As representative models, one staple crop model (millet) and one cash crop model (groundnuts) represents the composition of activities within the agroforestry system. The introduction of an additional 122 trees into one hectare of land was calculated using the space and impact of an increasing tree crown on field crop production over a 20-year period[[3]](#footnote-4), as was the increase in biomass services from having more trees in the field, with a positive annual incremental 2 percent impact on yields starting after 5 years, when the trees have grown sufficiently to protect the crops.

### Table 3: Densification of gum arabic trees



1. The analysis also benefited from the IFAD Climate Adaptation in Rural Development (CARD) Assessment Tool to forecast yields for the two field crops taking into account predicted climate change, using a pessimistic scenario[[4]](#footnote-5) – starting from 2021 until 2040.

### Chart 1: Climate affected crop yield forecast, using CARD Tool, 2018=0



Note: Includes with and without project impact scenarios.

1. The estimated total number of trees planted (or more often seeded) over five years is slightly over 39.3 million across all three states over a total of 125,000 hectares. The figure assumes a 70 percent survival rate in the first two years, with a 30 percent replacement value in the second year, after initial seeding or planting. The expected number of remaining trees in the ground is just above 30 million.

### Table 4: Number of trees seeded or planted



1. The analysis also assumes better management practices in the tapping of the trees, extending the lifespan of the tree stock with the use of the *sonki[[5]](#footnote-6)* in place of the traditional small axe, while increasing the gum yield from the tree by 30 percent.[[6]](#footnote-7) Furthermore, an increase in the price of the gum is achieved by assisting tappers to harvest and condition clean, dry gum, leading to smallholder producers receiving a 40 per cent price premium[[7]](#footnote-8), while other gum products receive a 20 percent (project) premium for improved product quality and regularity of supply with off-takers.
2. Investments under **Component 2: Climate change adaptation at landscape level through establishment of livestock routes, restoration of rangelands and enhancement of policy/institutional environment** within livestock corridors look to improve livestock mobility, thus safeguarding gum trees and rangelands from overgrazing and damage from livestock, and increasing carbon sequestration by grassland across 151,000 hectares. The livestock corridors will act to help farming communities to co-manage resources with pastoralists by improving water supply infrastructure along the defined livestock routes, and to avoid resource use conflicts between the two groups by building on the experience of past projects and development partners.[[8]](#footnote-9) In the analysis, the contribution of rangeland restoration to improving the input to livestock directly is taken into account through improved productivity in meat and milk production and higher market prices. In addition, the economic benefits calculated also draw on increases in ecosystem services through carbon sequestration. Total project fund allocation amounts to 39 percent of USD 10 million, or USD 3.9 million.

## Financial Analysis:

1. Two types of model exist to capture the benefits of investments in - *Acacia senegal* *(hashab)* and *Acacia seyal* *(talha)* - gum arabic trees through agroforestry and reforestation activities of the project, using the cost-benefit analysis method, based on one hectare and a two hectare plot at the agroforestry household level. Under agroforestry, the model includes average figures for field crop inputs and output yields[[9]](#footnote-10), across North and West Kordofan states, while the reforestation model also includes the state of South Kordofan.[[10]](#footnote-11)
2. The ***agroforestry models*** (of 2 ha) comprise of millet and groundnuts field crops for the first fifteen-year period, followed by five-years of fallow land, covering a total of 20 years. An increasing tree crown, with a starting size of 400 cm2 (20x20cm), determines land use, which eventually increases to 22 square meters in a 6mx6m format over 20 years. Tree plantings in the second year of the project begin to feed into the model with harvesting beginning in year 8. The average rate of harvest increases incrementally each year until maturity. While *Acacia senegal* gum trees typically provide 2.5-3 kg of gum sap a year at full maturity, the model uses 0.25 kg per tree/year without the project, with a 30 percent increase with-project. The plans to densify areas involves moving from an 8x8m layout to a 6mx6m layout. As a result, an additional 122 trees are seeded or planted per hectare in the second year of the project. The project expects a 70 percent survival rate and a replanting ratio of 30 percent in the fourth year of the project. The net incremental benefit of project interventions in the agroforestry models at household level (two hectares) equates to USD 175-179, before financing, for North and West Kordofan, respectively. After financing, the net incremental benefit increases to USD 337 and USD 186 for North and West Kordofan. While the revenue increase in the final year of the project is minor when compared with the first year of the project, when the comparison is made with both final years of the with-project and without-project scenarios, the with-project scenario is around four times greater for any number of financial performance indicators. For example, in the case of household agroforestry model for West Kordofan, revenues for both WOP/WP (without-project/with-project) are *circa* USD 200 in year 1, while in the final year of the analysis, they drop to USD 90 in the WOP scenario and in the WP scenario, they maintain and increase to US 279 per annum. We can conclude that revenues and income after labour appear steady after 20 years, even after applying the negative impact of climate change, *i.e.* declining crop yields using the CARD tool, and the occurrence of extreme weather events (with good, moderate and bad years). This suggests that ***the*** ***project is able to counter declines in yields, as forecast in the IFAD CARD tool, or revenues and earnings as a result of climatic change and extreme weather events.*** The preliminary results suggest greater resilience of the farming systems to climate change challenges.
3. An additional with-project scenario was developed to analyze the impact of ‘without private sector’ (WOPS) financing on the cash flow of agroforestry and reforestation activities, in addition to the ‘before’ and ‘after’ (blended) financing scenarios. The variation in performance indicators between after (blended) financing and after WOPS financing shows, for example, a slight decline in the incremental difference between the two scenarios. Taking the North Kordofan case as an example, we see that the incremental difference ‘before’ financing is USD -205, after the second year of intervention, however in the after financing scenario (with blended financing) the incremental difference is improved up to USD -1. In the WOPS financing scenario this figure declines slightly to USD -16. Either way, the WOPS and blended financing scenarios show that the contribution of the project, without which the private sector would not contribute, makes a substantial contribution to the incremental difference per hectare of intervention, and strongly suggests that the project provides sufficient incentives for farmers to improve and continue in sustainable practices.

### Table 5: Financial performance indicators for agroforestry activities, before and after financing, with project, per household (2ha)



1. Two types of ***reforestation models*** exist, with densification of 10x10m lands changing to 4x5m and 6x3m layouts for both *Acacia senegal* and *Acacia seyal*. *Acacia senegal* (hashab) trees represent around 80 percent of gum trees in Sudan, and so the models reflect this with 83 percent of the land in South Kordofan taken as *senegal* and the remainder as *seyal*. The more sandy soils in the north are typically more suitable to *hashab*, so the modelling for North and West Kordofan use only hashab trees, while the more clayey soils in the south are suited also to the *talha*, with a said 65 percent sandy and 35 percent clay soil composition. Half of the clay soil is also hashab, so only 18 percent, or 7 000 ha, is *talha* in the modelling for the southern state.
2. The reforestation model assumes planting or seeding of gum trees in the second year of the project by gum producers, and in return, the producers are permitted to cultivate the land with annual field crops such as sorghum and sesame, under the so-called modified *taungya* system with which FNC has decades of experience.[[11]](#footnote-12) Field crops begin in the third year of the project and continue for five years. Gum is first harvested in year 8, and when harvesting of gum begins the cultivation of field crops stops. Under this scheme a strong incentive is put in place for the planting of trees- by gum producers - with the reward of additional land for food and cash field crops. Before financing, the net incremental benefit of project intervention ranges between USD 189 and USD 268 per hectare. The financial internal rate of return ranges between 19 and 41 percent, while NPV ranges from USD 16 to USD 353 per hectare. Using modest assumptions for the yield improvements under *taungya* system, gross revenues and net income after labour costs increase substantially as a result of project interventions.

### Table 6: Financial performance indicators for reforestation activities, before and after financing, with project (per household)



NB: #NUM! occurs when a calculation does not return a number.

1. After financing, a number of financial performance indicators increase further, including the NPV, BCR and net incremental benefit (in USD). NPV almost doubles in a number of instances under reforestation activities.

1. The ***rangeland model*** estimates the total number of livestock that is likely to benefit from the improved pasture and the potential improvements in meat and milk output productivity. Around 13,338 herders are estimated along the livestock corridors to benefit from the pasture. Each herder is estimated to have 98 tropical livestock units (TLU). Given the vast land area, productivity is estimated to improve by only two percent as a result of the pasture improvement efforts. This is translated into minor improved earnings for the herders from meat and somewhat more from milk, due to improved access to water – following establishment of watering points along the new livestock corridors funded by the project.

1. The ***project level financial analysis*** returns an NPV of USD 3.9 million, a FIRR (financial internal rate of return) of 23 percent and a BCR of 1.56.

### Table 7: Financial project level analysis





## Project-level Economic Analysis:

1. The economic analysis uses shadow pricing by converting financial prices using a conversion factor of 0.85 in conjunction with a social discount rate (SDR) of 10 percent, as used by GCF for comparable projects and past multilateral lending rates on projects by IFAD and the World Bank.[[12]](#footnote-13) [[13]](#footnote-14) Overall, the project suggests an economic internal rate of return (EIRR) of 21 percent and an NPV of US$ 12.8 million, over a 20-year period. The BCR returns a figure of 2.68, while switching values suggest that benefits would have to decrease by -63 percent and costs increase by 168 percent before returning zero for the project investments.

### Table 8: Economic project level analysis





1. It is worth noting here also the convening powers of the project to draw the private sector to the help of the GAPA members, who are the main target group of the project, in directing additional capital into the area to absorb increases in quantity and quality of gum production, resulting from improved management practices supported by the project. This will result in the further expansion of gum tappers into untapped areas where densification of gum tree stands as promoted by the project has not yet occurred. In doing so, it will provide a further incentive for gum producers to increase tree densities in these formerly untapped areas, generating additional climate change mitigation results through carbon sequestration.[[14]](#footnote-15) The experience from the AFD-funded pilot project that GAMS aims to scale up has proven that pre-financing of gum tappers can increase the area covered by tappers and the volume of gum produced three-fold.[[15]](#footnote-16) As GAMS creates similar expansion of smallholder gum production, private sector off-takers will increase pre-financing of GAPAs and their members as supply is improved. Due to the non-perishable nature of gum, gum tappers can easily gauge the market and determine the amount of supply, depending on market prices, and tap more (or less) trees as the market achieves organic growth. The GAMS project anticipates that at the end of 20 years, the total amount of gum production by the project beneficiaries will increase six-fold. The gum export market will be able to absorb this increase comfortably, as analyzed in the Prefeasibility Study (para 66).

## Sensitivity Analysis:

1. The sensitivity analysis tests the robustness of the figures against a number of events. Inherent in the base scenario for both the without and with project is the occurrence of good, moderate and bad years. This was reflected in the models by positing a 0-60-80-100 percent yield for tree and field crops, in addition to the CARD Tool figures for the field crops and the restricted space for field crops by an increasing tree crown. In total, the results were tested against 260 different scenarios, with the EIRR and NPV tested against 12 different scenarios. The initial adoption rate of 100 percent is aligned with project’s gradual implementation rate and the duration of the project, thereafter the adoption rate factors in drop-out rates after field crops are no longer cultivated to 95 percent and then later to 90 percent and 80 percent in the latter half of the 20-year discount period. The analysis tested the adoption rate by the project overall. Evidently, there is a break-even point (BEP) for the project to make a positive return - based on financial and economic factors alone and without environmental co-benefits. The project calculated the BEP to be an adoption rate of between 45-50 percent, based on the calculations made thus far. The project is very likely to remain above this rate based on other project experiences mentioned earlier, *i.e.* the AFD-funded pilot project where the adoption rate was 84%.

## Climate Change Mitigation Benefits:

1. The analysis uses IPCC Tier 2 figures for calculating the project’s likely impact on greenhouse gas emissions reductions and carbon sequestration, based on the 125,000 hectares of reforestation and agroforestry ecosystem development and 151,000 hectares of grassland restoration in the rangeland areas. The results of the analysis suggest positive carbon sequestration numbers with 9,228,818 tons of CO2 sequestered over the 20-year period. The analysis used three different price points to quantify the environmental benefits by using the market, low and high social values of carbon, as defined by the High–Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern, and communicated in the September 2017 Cover Note on shadow pricing of carbon in economic analysis, by the World Bank.[[16]](#footnote-17) The climate change mitigation benefits have a substantial impact on the financial performance indicators, as detailed in Table 9 below. The Economic Internal Rate of Return (EIRR) without environmental benefits (WOEB) is above the discount rate of 10% at 21%, while the EIRR with the carbon sequestration benefits increases to 23%, even at current low market prices for GHG emissions reductions and removals, which are significantly below the social value of carbon (see Table 10). More notably, the Net Present Value (NPV) figures increase more than two-fold with low social carbon pricing and close to three-fold with high social carbon pricing, as per World Bank guidelines. The share of environmental co-benefits of total benefits with market values amount to 13.5 percent of total benefits, while with low and high social carbon pricing the share of environmental co-benefits amounts 48.3 percent and 65.1 percent, respectively, of total benefits. This suggests a high return of investment with respect to environmental benefits.
2. While the Economic Rate of Return to the project activities may seem high once ER benefits are included, from the beneficiary standpoint, the GCF grant funding is essential. Commercial financial institutions would not be willing to provide smallholder gum producer groups with the initial funds necessary to build their technical and organizational capacity and reposition them in the gum value chain. In addition, gum farmers would be unable to get the ER they generate through their agroforestry activities to market, in part because of the high transaction cost of verifying ER in dispersed, small landholdings. The global social benefit from the 9.28 million tCO2e of emissions reductions generated by GCF’s USD 10 million grant is considerable and the grant is highly efficient, if compared to the Forest Carbon Partnership Facility, which uses a USD 5/tCO2e standard purchase price, would have paid USD 46.1 million for the ER generated.

### Table 9: Climate Change Mitigation Benefits of Carbon Sequestration



### Table 10: Market and social value of carbon (USD per ton)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  | Years |  |  |  |  |  |  |  |  |  |  |  |
| USD/ton | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
| Market | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Low | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 55 | 56 | 57 | 58 | 60 | 61 | 63 |
| High | 82 | 84 | 86 | 87 | 89 | 91 | 94 | 96 | 98 | 100 | 102 | 105 | 105 | 109 | 112 | 114 | 117 | 120 | 122 | 125 |

Source: World Bank, ‘Guidance note on shadow price of carbon in economic analysis’, November 2017,

## Appendices

## Appendix 1: Financial and Economic Analysis Tables

Table 1: Conversion Factors



Table 2: Financial and Economic Prices



Table 3: Aggregation table



Table 4: Livestock data



Table 5: Financial Project Costs



Table 6: Financial Project Summary



Table 7: Economic Project Summary



Table 8: Environmental Co-Benefits



1. For this analysis, North and West Kordofan are lumped together for two reasons: (i) climate and farming systems in the two States are very similar (in contrast to South Kordofan); and (ii) there are no longer-term climate data for West Kordofan, which was created recently, and the project Localities in West Kordofan were formerly part of North Kordofan. [↑](#footnote-ref-2)
2. The adoption rate of 80 percent is considered conservative, given that a higher adoption rate of 84 percent was experienced under the AFD-funded SGAS pilot project, where 16 out of 19 groups remained with the programme, so the project is likely to match and exceed this figure. [↑](#footnote-ref-3)
3. Includes a two-year gestation period before introduction of new trees. [↑](#footnote-ref-4)
4. CARD has three basic yield reduction scenarios associated with optimistic, median and pessimistic emission scenarios. However, since GHG emission have increased rapidly in recent years, the pessimistic scenario appears most relevant. [↑](#footnote-ref-5)
5. *Sonki* is an improved hand tool that combines a chisel with a hook shape. It allows the tapper to strip just the bark of the tree to obtain the gum exudate, and avoid doing damage to the wood – which causes disease and reduces the productive lifespan of the tree – with the small axe that is used traditionally. The *sonki* has the added advantage of being easier to use for women, and of reducing injury to the tapper from the long and sharp Acacia spines. [↑](#footnote-ref-6)
6. International Journal of Environmental Planning and Management; “Management of *Gum arabic* Production Potentialities in the Gum Belt in Kordofan, Sudan”, 2016. [↑](#footnote-ref-7)
7. The resulting 40% increase in financial prices used in the analysis is conservative in comparison to the 50-55% price premium achieved by smallholder gum producer groups participating in the AFD-financed pilot project that GAMS intends to scale up. [↑](#footnote-ref-8)
8. Notably SOS Sahel and IFAD’s Livestock and Rangeland Resilience Programme (2014-2021) and Western Sudan Resource Management Programme (2004-2016) [↑](#footnote-ref-9)
9. FAO 2018 Crop and Food Supply Assessment Mission, Sudan using the past three years (2015/2016, 2016/2017, 2017/2018) where available. [↑](#footnote-ref-10)
10. International Journal of Environmental Planning and Management; “Recent Changes in Local Marketing Patterns of *Gum arabic* in Kordofan, Sudan”, 2016. [↑](#footnote-ref-11)
11. The *taungya* system was first devised in India under colonial rule, as a way to reduce labour costs for reforestation of government land. In Sudan, the system has been modified so that farmers not only benefit from the right to cultivate crops as the trees grow, but also share in the subsequent gum proceeds. This is especially attractive to farmers with little or no land, who are among the most vulnerable to climate change. [↑](#footnote-ref-12)
12. Livestock Marketing and Resilience Programme, IFAD (2014). While Sudan has remained cut-off from international lenders, past sovereign debt by bilaterals and multilaterals continues to be charged interest at around 10-12 percent per annum. <https://jubileedebt.org.uk/countries/sudan> [↑](#footnote-ref-13)
13. The SDR rate is twelve percent. [↑](#footnote-ref-14)
14. Since these additional mitigation results are not directly attributable to the project, they have not been included in the Ex-ACT assessment. [↑](#footnote-ref-15)
15. Hasan Mofadal, ‘Contract Farming Agreements between Gum Arabic Producers Associations (GAPAs) and Private Sector in Sudan: Cases and Experiences’, December 2017. [↑](#footnote-ref-16)
16. <http://pubdocs.worldbank.org/en/911381516303509498/2017-Shadow-Price-of-Carbon-Guidance-Note-FINAL-CLEARED.pdf> [↑](#footnote-ref-17)