A. Background

As indicated in the proposal, traditional rain fed agriculture – the predominant production system in rural Sudan – has become excessively risky and uncertain due to increasing climatic variability and competitive pressures on natural resources. Emerging climatic trends such as declining precipitation, more frequent drought episodes, higher temperatures, more intense sandstorms are leading to a sharp degradation of natural resources and exposing farmers to higher risks. The project comprises 3 outputs in addition to "project management", sub-divided into a total of 9 activities as shown in Table 12(a).1.

Table 12(a).1: Outputs and Activities

Outputs		Activities
1.	Resilience of food production systems and food insecure communities improved in the face of climate change in Sudan, benefiting at least 200,000 households of farmers and pastoralists with 35% women.	Activity 1.1: Introduction of drought-resilient seed varieties of sorghum, millet, groundnut and wheat that have demonstrated greater yields in the face of climatic changes through village procurement systems. Activity 1.2: Introduce sustainable practices in agricultural production at the community level. This involves the introduction of greater irrigation efficiency in the management of water resources through the introduction of integrated women's farms, home gardens, and demonstration plots. Activity 1.3: Introduction of rangeland management practices that reduce pastoral stress on communal lands through demonstration farms and rangeland rehabilitation techniques. Activity 1.4: Establish shelterbelts/agroforestry to improve productivity and reduce land and environmental degradation. This involves the plantation of trees to absorb energy from dust storms and protection of cultivatable areas.
2.	Improved access of water for human, livestock and irrigation to sustain livelihoods in the face of climatic risks in the nine targeted states benefiting at least 200,000 households.	Activity 2.1: Construct/rehabilitate water yards and drilling of shallow/borehole for drinking water for human and livestock and small-scale irrigation in targeted locations. This involves increasing the access to water by installing communal water infrastructure. Activity 2.2: Establish sand water-storage dams in support of small-scale irrigation in targeted localities and villages. This involves the blocking seasonal wadis for groundwater storage and exploitation. Activity 2.3: Construct improved Hafirs and upgrade of existing ones, excavating natural pond and cistern to increase availability of drinking water. This involves the construction of water storage infrastructure.
3.	Strengthened capacities and knowledge of institutions and communities on climate change resilience and adaption.	Activity 3.1: Train extension officers and other government stakeholders on climate change resilience and adaptation related issues. This involves the development of training materials tailored to local circumstances and delivered through a series of workshops. Activity 3.2: Build capacity of beneficiaries for coping with climate change risks and local operation & maintenance of project interventions. This involves a series of seminars and workshops to raise awareness among village leaderships councils about climate change coping strategies.
4.	Project management	

Economic values (costs and benefits) are all measured in real terms of 2019. Economic costs of the project are net of taxes, duties, and price contingencies. Furthermore, the analysis assumes a shadow wage rate of 1.00 for unskilled and semi-skilled labor in Sudan. Provided that the economic cost of labor in Sudan is expected to be lower than the market wage rate (financial cost), we expect this assumption leads to significantly over-estimating the economic cost of the project, and under-estimating the true net economic value of the project. The above assumption allows the use of financial cost as a measure of the economic cost of the project (once again noting that in doing so, the economic cost of the project is over-estimated, and the net present value of the investment is then under-estimated).

As is common when undertaking the economic analysis of investment projects, numerous assumptions were used to delineate the "with project scenario" from the "without project scenario". These assumptions

are presented and discussed below. In all cases where assumptions had to be made, we have adopted conservative assumptions so as to avoid over-estimating the expected benefits of the project. We thus believe that the analysis under-estimated the true economic benefits of the project. The analysis period is 25 years (Year 1 to 25).

B. Costs of the proposed investment project

B.1 Capital cost

Per funding proposal, the total cost of the project amounts to $41,185,114. The requested GCF grant amounts to $25,645,114 with a total co-financing of $15,540,000 of which the Government of Sudan (GoS) will provide $15,000,000 and UNDP will provide an additional $540,000.

The funding proposal shows the breakdown of GCF and non-GCF grant for each component of the project as shown in Table 12(a).2. The "budget and procurement planning tool" file allows breaking down the financing of the project by output by source of funding and by year. These are presented in Table 12(a).3 and 12(a).4. Total project capital cost is presented in Table 12(a).5. Table 12(a).6 presents the annual and cumulated percentage distribution of project implementation in any given year (as a percentage of the total project capital cost). All of these are shown in the "Costs" worksheet of the Excel file, row 1 to 35.

Table 12(a).2: Project Cost per Component and Source of Funding

		Co-financing		
Output	**GCF**	**UNDP**	**Gov of Sudan**	**Total**
Output 1	9,126,212	0	4,372,000	**13,498,212**
Output 2	14,321,347	0	9,578,000	**23,899,347**
Output 3	1,324,110	0	1,050,000	**2,374,110**
Management cost	873,445	540,000	0	**1,413,445**
Total	**25,645,114**	**540,000**	**15,000,000**	**41,185,114**

Table 12(a).3: Co-financing by Output and by Year

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Output 1	874,400	874,400	874,400	874,400	874,400	**4,372,000**
Output 2	1,915,600	1,915,600	1,915,600	1,915,600	1,915,600	**9,578,000**
Output 3	210,000	210,000	210,000	210,000	210,000	**1,050,000**
Management cost	-	-	-	-	-	**-**
Total	**3,000,000**	**3,000,000**	**3,000,000**	**3,000,000**	**3,000,000**	**15,000,000**

Table 12(a).4: GCF and UNDP Funding by Output and by Year

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Output 1	1,829,476	2,147,566	2,099,497	2,036,736	1,012,937	**9,126,212**
Output 2	3,255,044	3,005,794	2,980,544	2,978,295	2,101,670	**14,321,347**
Output 3	338,194	264,174	232,574	182,574	306,594	**1,324,110**
Management cost	354,939	327,439	243,689	243,689	243,689	**1,413,445**
Total	**5,777,653**	**5,744,973**	**5,556,304**	**5,441,294**	**3,664,890**	**26,185,114**

Table 12(a).5: Total Project Capital Cost by Output and by Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Output 1	2,703,876	3,021,966	2,973,897	2,911,136	1,887,337	**13,498,212**
Output 2	5,170,644	4,921,394	4,896,144	4,893,895	4,017,270	**23,899,347**
Output 3	548,194	474,174	442,574	392,574	516,594	**2,374,110**
Management cost	354,939	327,439	243,689	243,689	243,689	**1,413,445**
Total	**8,777,653**	**8,744,973**	**8,556,304**	**8,441,294**	**6,664,890**	**41,185,114**

Table 12(a).6: Percentage of Project Implementation
(as a percentage of project total capital cost)

	Year 1	Year 2	Year 3	Year 4	Year 5
Annual disbursement of total cost (%)	21.3	21.2	20.8	20.5	16.2
Cumulative disbursement (%)	21.3	42.5	63.3	83.8	100.0

B.2 Operation and maintenance costs

In order to sustain water system structures over their assumed life time, the National Water Council of Sudan recommends the use of various percentages to assess annual operation and maintenance (O&M) costs for different types of infrastructure. These O&M include: labor cost, fuel and lubricants, and fast-moving spare parts. The details of the estimation of the O&M are presented in the worksheet "O&M" of the Excel file and summarized in Table 12(a).7 below.

Table 12(a).7: Estimated Annual Operation and Maintenance Costs

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
69,000	138,000	207,000	276,000	548,750	548,750
Year 7	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**
548,750	548,750	492,500	548,750	548,750	548,750
Year 13	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**
548,750	492,500	548,750	548,750	548,750	548,750
Year 19	**Year 20**	**Year 21**	**Year 22**	**Year 23**	**Year 24**
492,500	548,750	548,750	548,750	548,750	492,500
Year 25					
548,750					

B.3 Total project costs

The resulting total project costs are presented in Table 12(a).8. The calculation is shown in row 37 to 46 of the same worksheet.

Table 12(a).8: Estimated Total Project Costs

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
8,846,653	8,882,973	8,763,304	8,717,294	7,213,640	548,750
Year 7	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**
548,750	548,750	492,500	548,750	548,750	548,750
Year 13	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**
548,750	492,500	548,750	548,750	548,750	548,750
Year 19	**Year 20**	**Year 21**	**Year 22**	**Year 23**	**Year 24**
492,500	548,750	548,750	548,750	548,750	492,500
Year 25					
548,750					

C. Project benefits

For purpose of the economic analysis, project benefits are sub-divided into 3 parts: (1) Benefits associated with greater access to water; (2) Benefits associated with greater crop yields; and (3) Benefits associated with higher irrigation efficiency. Details of the calculations are presented below.

C.1 Benefits of greater access to water

Better access to water supply is an important benefit of the project. The combination of high poverty levels and inadequate physical access to nearby water supply place a heavy burden on women and girls to fetch these vital resources from far beyond the village locale. The benefits of increased and nearby water supply will help to improve the quality of life for women and girls.

The economic valuation of the benefit of improved access to water relies on the following components and assumptions:

- Gross national income per capita is reported to be USD1,920 (measured in current dollars of 2015).[1]
- The total number of days per workweek is assumed to be 5; the total workdays per year is assumed to be 260. Assuming a 8-hour working day, average hourly income is estimated to be USD0.92.
- As indicated in the proposal, the total number of direct beneficiaries in the target communities is estimated to be 1,181,538 across 9 states of whom 413,538 are female. While the project also includes a large number of indirect beneficiaries (estimated to be 2,593,038), the estimation of the potential benefits of greater access to water and alternative energy supplies is based solely on the number of *direct* beneficiaries, and does not include indirect beneficiaries. To this extent, estimated benefits may represent an under-estimate of total potential benefits of this activity.
- The total number of hours spent per day is estimated to be 2 hours per day for water fetching. With the project activities, it is estimated that this total number of hours will fall by an average of 50% across all project sites. For purpose of the economic analysis, it is conservatively assumed that this time saving has economic value (benefit) only for the 260 days assumed to be working days.
- Finally, it is assumed that the total benefits of this project interventions increase over the 5 years of project implementation in the cumulative proportion of capital disbursement over the course of these 5 years.
- Given the above assumptions, estimated benefits of greater (improved) access to water supply are shown in Table 12(a).9 below. The calculation is presented in the worksheet “Benefits to women & girls” in the attached Excel file.

[1] Source: World Bank Development Indicators (http://data.worldbank.org/country/sudan).

Table 12(a).9: Estimated Benefits of Greater Access to Alternative Energy Supplies and Water Supply

Year	Water supply
Year 1	0
Year 2	211,527
Year 3	422,265
Year 4	628,458
Year 5	831,879
Year 6 to 25	992,491

C.2 Benefits of crop productivity interventions

Improved crop productivity through improved access to drought-tolerant seeds is another major benefit of the project. The combination of higher temperatures and increasingly erratic rainfall patterns has led to lower productivity of traditional millet and sorghum seeds in the targeted areas. The benefits of new seed varieties that are better suited for changing climatic conditions will help to improve small holder farm productivity.

The economic valuation of the benefit of improved irrigation relies on the following components:

- The total cultivated area that can benefit from the introduction of new seed varieties covered by crop production-related portion of the investment with this project is about 20,000 hectares.

- Hudo (2016)[2] recently assessed the impacts of climate variability and change on sorghum yield using AquaCrop model. Results show a decline in average sorghum yield of approximately 40% by 2046 due to projected decline in rainfall, and increase in minimum and maximum temperature. The average predicted future simulated sorghum yield for (2017-2046) is 372.3 kg/ha, compared with the observed sorghum yields for (1970-2000) of 616.2kg/ha. For purpose of the economic analysis it is assumed that net benefits from rain-fed agriculture would decline by 30% in Year 25 (to account for the shorter time horizon of the economic analysis than the time horizon used in Hudo (2016), and that net agricultural benefits would decline linearly between Year 1 and Year 25.

- It is assumed that small holder farmers rely solely on traditional seeds. On average, the productivity of subsistence crops will be lower without access to drought-resistant seeds. To improve crops productivity in the traditional rain-fed agriculture, the Agricultural Research Corporation (ARC) has developed and released several early maturing, stable and drought tolerant varieties of millet, sorghum, groundnut, sesame and cowpeas. Based on these experiences, it has been estimated that the use of improved seed of early maturing varieties could lead to significant increase in yield ranging from 10 to 30 % depending on the type of crops. Discussions with experts from ARC indicated that an increase of between 12% to 15% could be assumed as an average, based on records from the Variety Release Committee of the ARC. In the context of this analysis, it is conservatively assumed that providing seeds will lead to about a 12% increase in annual yield, on average above the projected yield in the scenario without project.

- Based on agricultural statistics published by the World Bank, the current yield per hectare of cultivated land (rainfed and irrigated) is about US$ 3,166/ha[3]. According to the Agricultural Research Corporation, the average productivity (kilogram / feddan) for rainfed agriculture ranges between 74%

[2] Hudo, N.A. 2016. *Assessing the Impact of Climate Variability and Change on Sorghum Yield over Gadaref Area in Sudan*. Mimeo. University of Nairobi, Kenya.
[3] Source: https://data.worldbank.org/indicator/NV.AGR.TOTL.CD

and 87% of the national average productivity (see Table 12(a).10 below). For purpose of the economic analysis, it was assumed that the rainfed-only current yield per hectare is 80% of this value, or US$ 2,533/ha.

Table 12(a).10: Average productivity(kg/Feddan)* of the main food crops in the rain-fed sector

Source	Sorghum	Millet
Sudan (national)	257	162
Sudan (trad. rain-fed)	190	141
Rain-fed yield as % overall national average yield	74	87

* 1 feddan = 0.42 Hectare

- Finally, as for the water supply component, it is assumed that the total benefits of this project interventions increase over the 5 years of project implementation in the cumulative proportion of capital disbursement over the course of these 5 years.

The estimated benefits of greater crop yields are presented in Table 12(a).11 below. These are shown in the worksheet “Benefits to agriculture” of the attached Excel file.

Table 12(a).11: Estimated Benefits of Greater Crop Yields

Year	Estimated benefits
Year 1	0
Year 2	1,279,273
Year 3	2,521,107
Year 4	3,703,533
Year 5	4,853,217
Year 6	5,695,200
Year 7	5,618,400
Year 8	5,541,600
Year 9	5,464,800
Year 10	5,388,000
Year 11	5,311,200
Year 12	5,234,400
Year 13	5,157,600
Year 14	5,080,800
Year 15	5,004,000
Year 16	4,927,200
Year 17	4,850,400
Year 18	4,773,600
Year 19	4,696,800
Year 20	4,620,000
Year 21	4,543,200
Year 22	4,466,400
Year 23	4,389,600
Year 24	4,312,800
Year 25	4,255,440

C.3 Benefits of small-scale irrigation interventions

Better water availability through improved irrigation access is one of the major benefits of the project due to the increasingly erratic nature of rainfall patterns in the targeted areas. Irrigation will help to offset dependence only on rainfed agriculture. The benefits of improved access to irrigated subsistence agriculture in the targeted communities will lead to improved annual average productivity of subsistence crops. The economic valuation of the benefit of improved irrigation relies on the following components:

- The total cultivated area that will be covered by irrigation-related portion of the investment with this project is about 5,000 hectares.

- It is assumed that small holder farmers rely solely on rainfed agriculture in the absence of access to irrigation. On average, the productivity of subsistence crops will be lower without access to irrigation. It is conservatively assumed that providing access to irrigation will lead to about a 12% increase in annual yield, on average.[4]

The estimated benefits of greater crop yields are presented in Table 12(a).12 below. These are shown in the worksheet “Benefits to water resources” of the attached Excel file.

Table 12(a).12: Estimated Benefits of Greater Crop Yields

Year	Estimated benefits
Year 1	0
Year 2	728,546
Year 3	1,435,770
Year 4	2,109,162
Year 5	2,755,202
Year 6	3,243,416
Year 7	3,199,679
Year 8	3,155,941
Year 9	3,112,204
Year 10	3,068,466
Year 11	3,024,728
Year 12	2,980,991
Year 13	2,937,253
Year 14	2,893,516
Year 15	2,849,778
Year 16	2,806,040
Year 17	2,762,303
Year 18	2,718,565
Year 19	2,674,828
Year 20	2,631,090
Year 21	2,587,352
Year 22	2,543,615
Year 23	2,499,877
Year 24	2,456,140
Year 25	2,423,473

[4] Source: Food and Agricultural Organization (FAO), Agricultural Research Cprporation (ARC), and Water Harvesting Research Institute (WHRI) *Demonstration of Water Management Practices in Dry Land Areas* (DEWNAP). TCP/SUD/3302.

D. Net present value and internal rate of return

As reported in the worksheet "NPV and IRR" of the attached worksheet, the net present value (NPV) of the proposed investment project is estimated to be USD27.8 million. The internal rate of return is estimated to be 21.9%.

E. Sensitivity analysis

A sensitivity analysis was conducted with the following 3 scenarios: (1) 10% increase in cost; (2) 10% decrease in benefits; and (3) 10% increase in cost combined with a 10% decrease in benefits. The outcome is presented in Table 12(a).13. Details are presented in the worksheet "NPV and IRR", row 34 to 128. The outcome of the economic analysis is robust to these changes. The only scenario where the IRR falls slightly below 10% is when costs were to increase by 30% and benefits *simultaneously* decrease by 30%.

Table 12(a).13: Base case and sensitivity analysis (NPV; IRR)

	Costs scenarios			
	Base case	**+10%**	**+20%**	**+30%**
Benefits scenarios				
Base case	$41,1; 27.1%	$24.3; 19.6%	$20.8; 17.6%	$17.3; 15.9%
-10%	$20.9; 19.3%	$18.0; 17.2%	$14.5; 15.4%	$10.9; 13.8%
-20%	$15.2; 16.7%	$11.7; 14.8%	$8.2; 13.1%	$4.7; 11.6%
-30%	$8.9; 14.0%	$5.4; 12.2%	$1.8; 10.7%	$1.6; 9.4%

Since agricultural benefits represent a relatively large share of the total benefits of the project, it is of interest to perform sensitivity analysis for this sole benefit. As noted above the base case analysis assumed that productivity (yield per ha) would be 12% higher than it would otherwise be in the absence of the project. The sensitivity analysis shows that as long as the gain in productivity as a result of the project intervention reaches at least 3.2% (above the projected yield without project), then the project delivers a positive NPV and an internal rate of return above 10%.