



This project is co-funded by the European Union



german cooperation
DEUTSCHE ZUSAMMENARBEIT



Nexus Assessment

Synergies of the Water, Energy and Food Sectors in Sudan



giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by

Nexus Regional Dialogue Programme (NRD)



c/o Deutsche Gesellschaft für Internationale
Zusammenarbeit (GIZ) GmbH



Registered offices: Bonn and Eschborn, Germany

Global Nexus Secretariat (GNS)

Sector Programme Sustainable Water Policy
Division Climate Change, Environment & Infrastructure (G310)
Department Sector and Global Programmes
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Programme

The Nexus Regional Dialogue Programme (NRD) is a programme funded by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ).

This publication has been produced on behalf of the European Union and Germany (German Federal Ministry for Economic Development and Cooperation, BMZ). GIZ is responsible for the content of this publication. The content does neither represent the opinion of the European Union nor Germany (BMZ).

Place and date of publication

Eschborn, 2019

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Photo Cover

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LIST OF ABBREVIATIONS

Abbreviation	Full name
AOAD	Arab Organization for Agricultural Development
ARC	Agricultural Research Corporation
AARP	Agricultural Revival Plan
AWM	Agricultural water management
BMZ	German Ministry for Cooperation and Economic Development
CAADP	Comprehensive African Agricultural Development Programme
DIU	Dams Implementation Unit
EU	European Union
FAO	Food and Agricultural Organization
FNC	Forests National Corporation
GM	Green Mobilization
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCNER	Higher Council for Environment and Natural Resources
HRC	Hydraulics Research Centre
IPRSP	Interim Poverty Reduction Strategy Paper
JICA	Japan International Cooperation Agency
MENA	Middle East and North Africa
MA&F	Ministry of Agriculture and Forests
MFNE	Ministry of Finance and National Economy
MLRFP	Ministry of Livestock Resources, Fisheries and Pastures
MOAF	Ministry of Agriculture and Forests
MWREI	Ministry of Water Resources, Electricity and Irrigation
NAPA	National Adaptation Program Action
NCWR	National Council for Water Resources
NRD	Nexus Regional Dialogue
NREC	National Research Energy Centre
UNEP	United Nation Environment Programme
WEF	Water-Energy-Food (Nexus)
WUAs	Water Users Associations

EXECUTIVE SUMMARY

Background

The Nexus approach, unlike the prevailing sector-oriented approach, emphasizes building integrated cross-sector synergies and perspectives, acknowledging the integrative nature of the three sectors. This allows to strengthen processes aimed at meeting growing water, energy and food security demands in a sustainable way. The Nexus approach, furthermore, supports tackling key global challenges such as climate change and the increasing degradation of ecosystems and their services in line with achieving the Sustainable Development Goals.

Based on the interest expressed by the Sudanese Ministry of Water Resources, Electricity and Irrigation, the Nexus Regional Dialogue in the MENA Region¹ took the initiative to develop a Nexus Assessment Study for Sudan in collaboration with the Arab Organization for Agricultural Development (AOAD). The study was carried out by Humboldt University in Berlin, Germany, the International Food Policy Research Institute (IFPRI) and the University of Khartoum in Sudan. The views of different experts and stakeholders were taken into consideration in this study, through organizing a national dialogue on WEF Nexus in Sudan as well as a validation workshop, where the main findings and recommendations of the study were presented and discussed.

This report presents the main findings of the Nexus assessment study for Sudan. It identified Water-Energy-Food Nexus priority issues in Sudan, suggested operational guidance to align national strategies, policies and implementation plans within a national Nexus framework, identified opportunities to apply the Nexus approach, including institutional settings and capacity building needs, and suggested a series of Water-Energy-Food Nexus projects in Sudan.

Summary of WEF Nexus Opportunities and Challenges in Sudan

The slow progress in agricultural productivity in Sudan is primarily a consequence of the inefficient use of available water and energy resources. Water, energy and food production and utilization in Sudan are characterized by abundance, though food production operates below potential amid population growth and growing food demands, changing climate conditions, weak policies and poor coordination among key government agencies.

Sudan is endowed with a substantial amount of natural resources and ample productive agricultural lands. About 63% of the land area of the country is classified as agricultural land including pastures and forest area. The ecological and climatic characteristics of Sudan suit the production of a wide variety of crops as well as animal husbandry. However, as resources are not properly utilized, Sudan still depends on food imports and faces increasing demands and pressures on its water, land, energy and food resources because of climate change and population growth.

¹ The Nexus Regional Dialogue in the MENA Region is one of several regional dialogues of the Nexus Dialogue Programme, co-funded by the EU and BMZ, aiming at strengthening the process of meeting increasing water, energy and food security demands in a sustainable way, through adopting the Nexus approach. See also: <https://www.nexus-dialogue-programme.eu/regional-dialogues/mena/>

Despite the plentiful water resources, including rainfall, rivers and underground sources, there are serious risks to the future of water security, mainly due to increasing water demand and the dependence of the country on shared or transboundary resources. Sudan is blessed with the River Nile, including tributaries of the Blue Nile and the White Nile, and has constructed five large irrigation dams for hydroelectric generation and to supply water for gravity irrigation. Rainfall ranges between nil in the extreme north and up to 800 mm per annum in the extreme south. Low water storage capacity and the low number of water control systems contribute to the inefficient use of water resources. Domestic water supply in urban and rural areas is insufficient and there are concerns about sanitation coverage.

Roughly 43% of the Nile basin, which is shared among 11 countries, lies within Sudan. Limited internal renewable water resources (IRWR) as well as the erratic nature of rainfall in Sudan – and its concentration in a short season – the country in a vulnerable situation, especially in rainfed areas. Total IRWR in Sudan amounts to 4.0 billion cubic meters/year. However, inflows are considerable, at 99.3 billion cubic meters/year (99.3% from the River Nile system and 0.7% from Eritrea), summing to total water resources of 103.3 billion cubic meters. Surface water storage in the country remains limited and was estimated at 21 billion cubic meters in 2011.

In terms of energy, Sudan faces the dual challenge of limited access to modern energy and heavy reliance on traditional biomass energy sources to meet its rapidly growing demands. Traditional biomass fulfills most of the energy needs of the local population, especially those who live in the countryside with no access to electricity. Fuel wood and charcoal provide for about 75% of its energy needs. Production of crude oil decreased from 8,380 thousand tons of oil equivalent (KTOE) in 2000 to 6,950 KTOE in 2015. By 2016, only 38.5% of the total population was connected to the national grid. The rate of electricity access is high in urban areas (62%) but remains extremely low in rural areas.

Power generation depends mostly on hydropower, with a total potential of 4,176 MW. Total installed capacity of hydropower and thermal power plants are 1,585 MW and 1,400 MW, respectively. Hydroelectricity is generated from the Roseires, Sinnar, Jebel Aulia, Khashm el-Girba, and Merowe dams.

Total electricity generation has increased from 4,125 GWh in 2005 to 11,848 GWh in 2014. About 75% of total production was met by hydropower. Sudan has started to import electricity, which contributed about 4% of total supply in 2014. Per capita electricity consumption was 190 kWh in 2014, far below the average level across Africa estimated at 500 kWh per capita per year and even further below the global average of 3,125 kWh/capita/year in 2014.

Renewable energy potential is high, particularly for solar, with mean solar radiation of 6kwh/m²/day, but also for wind. Renewable energy can play an important role in improving modern energy access in Sudan, improving energy security and contributing to climate change mitigation. The government plans to integrate renewable energy into the power system of Sudan with a target of 20% by 2030. As the country's oil-dependent energy security severely weakened after 2011, the government opted for plans to import energy from Ethiopia and to construct new hydropower plants with foreign investment. However, the effectiveness of these measures is contested.

Key government strategies for power-sector development include: to utilize the renewable energy resources potential in Sudan to increase energy access throughout the country; to achieve a competitive price of energy from renewable sources; to diversify energy supply sources and ensure energy security; to support the national economy by technology and knowledge transfer, capacity building and promoting a local renewable-energy industry; and to provide access to electric-energy supply to rural areas far from the national grid or isolated grids for which the grid extension is not a feasible solution.

The responsiveness of farmers and investors to economic opportunity is closely linked to electricity access. The lack of adequate roads, electricity, storage facilities and other related services, as well as frequent power cuts and a shortage of diesel and gasoline, have resulted in high production costs, which have already driven business out of some activities.

There is also macroeconomic instability, which adversely affects investment and foreign exchange availability. The latter creates difficulties in the purchase of fuel inputs and capital goods. The decline in available external resources (from investors and creditors) contributes to the worsening of the macroeconomic environment. To this is added political instability that affects investor confidence.

The salient features of Sudan's geo-political and socio-economic structure are summarized in the following challenges and bottlenecks:

- 1) Dependence on external sources for provision of water, energy and food (particularly wheat, sugar and powder milk).
- 2) Dependence of agricultural economy on variable, erratic short-season rainfall.
- 3) Vulnerability to climate change and climate variability, as well as water scarcity in areas far from the Nile and its tributaries, energy deficiency, and food import dependency.
- 4) Poor enforcement of laws pertaining to protection of natural resources and *ad-hoc* crisis-management policies and plans.

Below is a summary of WEF resources, WEF Nexus sectors' critical linkages, risks and opportunities, and a brief summary of proposed projects to seize identified opportunities and address the challenges.

Water Resources & Rivers

Sudan is endowed with various water resources including the River Nile and its tributaries and several large seasonal streams, groundwater and rainfall. The use of water quantities among the different sectors in 2006 was 96.2% for agriculture, mainly from surface water resources, 3.5% for domestic use and 0.3% for industry.

Groundwater is only used in limited areas and mainly for municipal supply. Its exploitation is undertaken in an unplanned manner and there are problems of overexploitation and deterioration of quality.

Sudan's estimated annual rainfall since the secession of South Sudan has decreased from 1,060 billion cubic meters to about 442 billion cubic meters. Rainfall varies in amount and frequency, with amounts generally decreasing from south to north. The rainy season runs from June to September with a peak in August. Harnessing rainwater and floods is not widely practiced and water harvesting is poorly developed. Although the practice is old, it is only carried out on a limited scale. Rainwater is used to cultivate around 30 million feddans of millet and sorghum – for domestic consumption and export – in the traditional and the semi-mechanized rainfed sub-sector.

The future demand for water resources, as presented in the 25-year Sudan Development Strategy (2007-2031), is estimated at 59.2 billion cubic meters. This includes irrigation water needs of 42.5 billion cubic meters, human, animal and industrial needs of 10.1 billion cubic meters, as well as evaporation losses of 6.6 billion cubic meters, from existing and proposed hydropower projects (Sudan Policy and Strategy on Integrated Water Resources Management, 2007).

Energy Resources

Sudan has a variety of energy sources composed of electric, fossil, renewable and biomass energy, but only a small share of the population has access to clean, modern energy. Traditional biomass provides for most of the energy needs of the local population, especially those in rural areas. Fuel wood and charcoal provide about 75% of total energy needs. By 2016, only 38.5% of the total population was connected to the national grid. Access to electricity is high in urban areas, at about 62%, but remains extremely low in rural areas, at about 22% in 2016.

Summary statistics on energy are:

- Electricity per capita consumption: 190 KWh (world average is 3125 KWh, 2014)
- Total electric power consumption: 11796 GWh.
- Total electric power production: 14431 GWh.
- Imported electricity (from Ethiopia): 440 GWh.

Electricity supply is composed of two systems: the national grid that supplies limited zones – mainly central, north and eastern Sudan – and the off-grid system composed of isolated small-scale thermal power plants that supply remote cities or regions. Solar and wind energy are in their nascent stages. Regions in Sudan that do not have access to electricity from the national grid or the isolated grids rely on small diesel-fired generators for power.

Electricity supply and demand

The current and future demand for electricity in Sudan shows an expected gap between supply and demand, which entails bridging the deficit by building more dams, increasing thermal power generation units, increasing renewable energy and, most of all, increasing imports of electricity from Ethiopia. A combination of any of these sources is viable.

Food and Agriculture

Sudan is self-sufficient in basic subsistence crops for the majority of the population in rural areas. It imports supplementary wheat and sugar and other food items. About 3-7 million tons of cereals are produced annually. This is projected to increase to about 13 million tons by 2030 while projected demand is expected to be around 12 million tons.

The overall wheat import requirements amounted to about 1.652 million tons in 2016, constituting about 75% of domestic demand. To mitigate the impact of inflation, due to the deterioration of the Sudanese pound against the American dollar, the government subsidizes about 20% of the import costs in the form of a concessional exchange rate for importers.

Mapping relevant Institutions to the critical interlinkages in Sudan

Key Nexus sectors include:

- Water resources development, distribution, use and security
- Energy production, distribution, use and security
- Agriculture (food) land use, food production and food security
- Environment protection

- Sustainable development, including Sustainable Development Goal (SDG) implementation and integrated climate mitigation and adaptation

The key sector institutions in Sudan are the Ministry of Water Resources, Electricity and Irrigation (MWRIE), the Ministry of Agriculture and Forests (MA&F) and the Ministry of Oil, Gas and Minerals (MOGM). They are supported by other institutions, including the Agricultural Public Schemes Managing Boards, the Hydrology Research Centre, the Agricultural Research Corporations, the High Council for Environment and Natural Resources (HCENR), the National Council for Water Resources (NCWR) and the Ministry of Finance and Economic Planning (MFNEP). The State Ministries for Agriculture, Livestock and Irrigation and the State Ministries of Physical Planning and Finance are responsible for the planning and implementation of WEF at the state and local levels. Key international organizations and non-government actors include the FAO, IFAD, WFP, UNEP and UNDP. They provide technical and financial support to capacity building and carry out situation analyses to inform policy-making and management of water and other resources.

WEF Nexus Critical Linkages, Risks and Opportunities

The water subsector is the key factor in WEF Nexus interventions. Strengthening the water subsector means to better coordinate with and integrate the activities and plans of other subsectors including agriculture and energy, each of which depends on and/or affects water resources. Hence, water resources plans and policies need to be aligned with other sectors' plans, policies, strategies and measures. Agriculture uses about 97% of the country's extracted River Nile waters, and about 95% of the total area under crop production depends on rainfall. Sudan is not using its full share of water from the Nile, withdrawing between 14.0 and 16.5 billion cubic meters out of 18.5 billion cubic meters due to managerial and financial constraints.

The future demand for water in Sudan is projected to reach 48 billion cubic meters. In addition to financial requirements and good management, there is a need for a WEF Nexus approach to coordinate food and energy production in a way that conserves water resources.

The continued substantial dependence of Sudan on rainfed agriculture creates uncertainty and risk for farmers. It subjects crop production to variability in water availability and exposure to recurrent flood and drought cycles. Therefore, there is a need to focus on harnessing water technology using water-harvesting techniques in the rainfed production system to increase self-sufficiency of local communities and to provide synergies for the rational management of the water system. The construction of dams has created large reservoirs that could be used more comprehensively for fisheries production. Major dam-fisheries resources are found in Lake Nubia, Jabal Awlia Dam, Khasm Al-Girba Dam and at Rosaries Dam. One of the risks that threatens the availability of water for food is the influx of foreign investment for the production of wheat and fodder using underground water. There is a possibility that over-extraction would negatively affect the water table. Nexus analysis can help support the adequate development of water, energy and food production in relation to Sudan's groundwater potential to avoid groundwater drawdown.

Hydropower and thermal power generation dominate the overall source supply of electricity in Sudan. They are composed of two systems: the national grid that supplies limited zones – mainly the central, north and eastern Sudan – and the off-grid system composed of isolated small-scale thermal power plants that supply a few smaller cities and regions.

Public corporations and private-sector pump schemes rely on the use of diesel fuel for irrigation. Some of these schemes were transformed from diesel-powered pumps to electrically powered pump schemes. This helped in decreasing the cost of irrigation by almost 30%. Sudan also depends on imported diesel fuel for food and fodder production in largely rainfed areas and in areas irrigated close to rivers.

The problem with diesel fuel is that it is imported at high cost while reliance on hydro-electricity results in the irregular supply of power, especially during peak demand periods. Hence, an alternative solution is to look for sustainable and low-cost water pumping systems. Renewable energy systems, including solar and wind energy, may also be part of the solution. To this end, a project of the Sudanese Electricity and Distribution Company (SEDC) focuses on solar pumps and solar lighting systems. The project targets states that suffer from disputes as well as states that are far from the national grid. Other projects focused on renewable energy aim at increasing power generation from wind energy and solar pumps for irrigation.

Energy for agriculture and food production includes the provision of adequate energy supplies to meet the needs of pumping water, transportation, storage facilities and land preparation. In addition, crop expansion, diversification and intensification spurred by the new irrigation technology is associated with increased energy needs for distributing fertilizers and pesticides.

Sugarcane production supplies biomass for sugar refinery boilers. The energy produced is transformed into electricity to meet factory needs and could supply the national grid system.

Overall assessment, challenges and opportunities (solutions)

The main contributors to water, food and energy insecurity in Sudan relate to the inadequacy of the institutional set-up and governance (infrastructure development, insecurity and conflicts, poverty and mismanagement of resources to meet the growing demand for food). These factors have hindered timely decisions on development, management and maintenance of WEF Nexus sector activities. They are summarised along with opportunities below:

- The rural population has no access to electricity and therefore depends on fuelwood and charcoal. The resulting desertification has increased soil degradation and led to water stress, drought and consequent crop failure risking food security and reducing the potential for biofuel production.
- In general, the country as a whole suffers from food shortages, especially in wheat.
- Increased enforcement of government regulations and the creation of an enabling environment to attract foreign direct investment will accelerate solving many of the persistent WEF issues.
- A focus on water security will support water conflict resolution through increasing water storage in drought-affected areas and extending public services that include safe drinking water supplies and sanitation services.
- The increase in energy accessibility would positively affect water security and strengthen the willingness and abilities of rural people to access safe water sources independently.
- Increased energy demand driven by increased water services coverage could be met by improving renewable energy sources and biofuels and advancing water harvesting systems and techniques.

Sudan shares common surface and underground water resources with neighbouring countries. The cooperation between Sudan, Egypt and Ethiopia on the Blue Nile front has always been solid and recently has been strengthened by the construction of the Grand Ethiopian Renaissance Dam (GERD). Following the completion of the GERD mutual benefits will evolve that could support further transboundary projects.

However, cooperation in the Nile Basin has also been reduced because of the GERD, as Egypt (as the downstream country) sees risks from the potential of upstream countries controlling flows into Sudan and subsequently into its own territory. The cooperation of Sudan, Libya and Egypt on the Nubian Sandstone Aquifer is still premature.

Proposed dialogue and investment projects

The study proposes a number of dialogue programs and investment projects to bolster the WEF Nexus Approach. These include:

Three institutional dialogue proposals:

- Establishment of an integrated WEF cross-sector platform
- Gezira Scheme Nexus Dialogue and Pilot
- Regional Nubian Sandstone Aquifer Monitoring and Dialogue

A series of investment project proposals:

- Merowe Dam and Resettlement Project
- Blue Nile State Water Harvesting Project
- White Nile State Water Harvesting Project
- Khor Abu Habil Project
- Fisheries Development Project
- Solar home and irrigation in remote areas project
- Climate Change Adaptation in Remote Rural Areas
- Program on Improvement of Livelihood of rural people in Darfur States/Sudan

A short summary of these proposed activities is provided as follows:

Project 1: National WEF Nexus Platform

Budget: USD 1.5 million to be implemented by the state government and affiliated ministries of agriculture and irrigation

The objectives of this project are to:

- Enable existing bridging institutions and mechanisms to promote WEF Nexus integration and coordination.

The project has two components. The first component is to reorganize existing WEF sector and cross-sector institutions and the second component is to achieve capacity building of the WEF sectors institutions

Project 2: Gezira Scheme Nexus Dialogue and Pilot project

Budget: USD 1.8 million for 18 months

The objectives of this project are to:

- Establish dialogue to discuss tradeoffs between the interest of the tenants and the national economy (gain or save foreign exchange earnings)
- Pilot information and communication technology (ICT) system to increase two-way accountability between irrigation service providers and irrigators to:
 - a) Increase water use efficiency
 - b) Farmers' incomes

- c) Food security
- d) Energy use efficiency
- Link pilot improved extension, credit and marketing services

Project 3: Regional Nubian sandstone aquifer monitoring and dialogue

Budget: Approximately USD 1.5 million

The objectives of this project are to:

Promote regional cooperation, networking, monitoring, and implementation mechanisms with neighboring countries to facilitate equitable and fair share of supplies of adequate water for food production, based on mutual benefits of partners sharing the common water resources

Project 4: Merowe Dam Effects on the livelihoods of the resettled people project

Budget: USD 1.5 million

The objectives of this project are to:

- Develop resettlement guidance informed by Nexus thinking
- Strengthen agricultural managerial capacity of displaced people and the communities living within the Dam command area.
- Enhance the employment opportunities for local people, men and women.
- Install solar-energy rooftop and irrigation systems to compensate for shortage of the electricity supplied by the Dam.
- Rehabilitate the negative effects of the Dam on the microclimate of the domain area.

Project 5a: Blue Nile state water harvesting project

Budget: USD 600,000

The objectives of this project are to:

- Reduce energy use for pumping through groundwater recharge
- Improve water and food security through increased water availability
- Improve livestock productivity
- Increase water use efficiency

Project 5b: White Nile State Water Harvesting Project

Budget: USD 800,000

The objectives of this project are to:

- Supply drinking water for humans and livestock
- Reduce friction between crop and livestock livelihoods
- Use supplementary water for irrigation
- Use added crop residues for biogas

Project 5c: Khor Abu Habil Water harvesting

Budget: USD 200,000

The objectives of this project are to:

- Implement upstream/downstream Nexus dialogues across three states to identify mutual opportunities to improve water use efficiency and food security, for example, through the introduction of water scheduling tools, such as soil moisture sensors
- Possible extension of private-sector activities from North Kordofan to South Kordofan and White Nile states

Project 6: Rosaries Reservoir Fisheries Project

Budget: USD 200,000

The objectives of this project are to:

- Revitalize fishing activities of small producers in Roseires reservoir lake
- Increase WEF uses of Sudanese reservoirs
- Increase food and nutrition security

Project 7: Solar home and irrigation in remote areas project

Budget: USD 300,000

The objectives of this project are to:

- Use flexible solar panels for multiple purposes (i.e., irrigation and lighting for homes)
- Support development of on-farm and off-farm small enterprises

Project 8: Climate Change Adaptation in Remote Rural Areas

Budget: USD 300,000

The objectives of this project are to:

- Strengthen women's capacity for resilience against climate change
- Improve nutrition among rural populations
- Improve the use of solar energy

Project 9: Program on Improvement of Livelihood of rural people in Darfur States/Sudan

Budget: USD 6.1 million shared across different donors

The objectives of this project are to:

- Improve food security, alleviate poverty, increase resilience capacity against climate change and other risks, and improve the livelihoods of the people in Darfur states

تقييم الترابط في السودان- تآزر قطاعات المياه والطاقة والغذاء (ملخص تنفيذي)

1. خلفية عامة

يهدف نهج الترابط إلى تعزيز عمليات مقابلة الاحتياجات المتزايدة من المياه والطاقة والغذاء بطريقة مستدامة، من خلال توفيق السياسات المرتبطة بهذه القطاعات، ودعم ما تتطلبه من تعاون عبر القطاعات المتعددة وبين المستويات المختلفة في عمليات اتخاذ القرار. ومن خلال نهج الترابط يمكن التوصل إلى وضع سياسات وخطط توائم الاهتمامات الاقتصادية والبيئية والاجتماعية في تنافسها على الموارد المحدودة وذلك بخلاف ما هو سائد في التخطيط القطاعي. وتأتي أهمية نهج الترابط انطلاقاً من قدرته على تعزيز تنمية خضراء والتصدي للتحديات العالمية مثل تغيّر المناخ والتدهور المتزايد للأنظمة الحيوية والأراضي بجانب تحقيق أهداف التنمية المستدامة.

وبناء على الاهتمام المعلن من وزارة المياه والطاقة السودانية بادر الحوار الإقليمي للترابط في منطقة الشرق الأوسط وشمال إفريقيا، الممول من كل من الاتحاد الأوروبي ووزارة التعاون الاقتصادي والتنمية الألمانية² بإعداد هذه الدراسة لتقييم ترابط المياه والطاقة والغذاء في السودان، بالتعاون مع المنظمة العربية للتنمية الزراعية. وقام بإعداد الدراسة جامعة هامبولت Humboldt في برلين بألمانيا والمعهد الدولي لبحوث السياسات الغذائية (IFPRI) وجامعة الخرطوم. وقد تم تضمين آراء خبراء من مجالات عدة في هذه الدراسة من خلال حوار وطني حول الترابط في السودان تم تنظيمه في الخرطوم، كما تم تضمين نتائج ورشة عمل التحقق التي تم عقدها لمناقشة النتائج الأولية لهذه الدراسة والتعرف على آراء الأطراف الفاعلة المختلفة بخصوص التوصيات والحلول والمقترحات.

ويعرض هذا التقرير النتائج التي خلصت إليها دراسة تقييم الترابط في السودان والتي هدفت إلى تحديد موضوعات الترابط ذات الأولوية في السودان اقتراح توجيه عملي لتوفيق الاستراتيجيات والسياسات والخطط التنفيذية الوطنية في السودان ضمن إطار ترابط وطني، وذلك بتضمين ترابط المياه والطاقة والغذاء فيما يتعلق بالموارد الوطنية والأمن البشري، ورصد الفرص المتاحة لتطبيق نهج الترابط وما تتطلبه من إعداد مؤسسي وتنمية للقدرات البشرية، واقتراح مجموعة مشروعات تقوم على ترابط المياه والطاقة والغذاء في السودان.

2- ترابط المياه والطاقة والغذاء في السودان:

² الحوار الإقليمي للترابط في الشرق الأوسط وشمال إفريقيا هو أحد الأقاليم التنفيذية لبرنامج حوارات الترابط Nexus Dialogues Programme الممول من كل من الاتحاد الأوروبي ووزارة التعاون الاقتصادي والتنمية الألمانية. ويعمل البرنامج على تعميم نهج الترابط في عدة أقاليم على مستوى العالم، من خلال نقاشات رفيعة المستوى. <https://www.nexus-dialogue-programme.eu/regional-dialogues/mena/>

يتميز السودان بتوفر الأراضي، حيث تمثل المساحة القابلة للزراعة نحو 63% من مساحة القطر الكلية. كما يتميز السودان بخواص بيئية ومناخية ملائمة لزراعة أنواع مختلفة من المحاصيل ورعاية الثروة الحيوانية، إلا أن ما يعادل نحو 80-90% من الرقعة الزراعية يعتمد على الأمطار بكل يتمثل ذلك من انخفاض في مستوى تقنيات المدخلات والمخرجات.

ويتميز السودان بكميات وافرة من المياه من الأنهار والمياه الجوفية والأمطار، إلا أنه يعاني من نقص في الطاقة وتدني توفر البنية التحتية. وقد أدى عدم توفر هذين العاملين، خاصة في مجال وسائل النقل والطاقة، الى ارتفاع تكلفة الانتاج وضعف القدرة التنافسية لمنتجات الصادرات.

وقد أدت المعوقات المشار إليها منذ الستينيات، إلى ضعف وتدهور مساهمة قطاع الزراعة والثروة الحيوانية والغابات والأسماك في الناتج المحلي الأجمالي. وتمثل ذلك في انخفاض القيمة المضافة من القطاع الزراعي بكل مكوناته من نحو 46% من الناتج المحلي الاجمالي في الثمانينيات إلى نحو 36% في العام 2010/2013. وفي نفس الفترة ارتفع عدد السكان من حوالي 17 مليون نسمة إلى حوالي 25 مليون نسمة، علما بأن القطاع الزراعي يوفر فرص عمل ودخل لنحو ثلثي القوة العاملة بالسودان.

2-2 السمات الرئيسية لوضع المياه والغذاء في السودان

توجد ثلاثة عوامل رئيسية تعيق نمو القطاع الزراعي في السودان:

- الموارد المائية

يحظى السودان بموارد مائية متنوعة تشمل نهر النيل ورافده والأنهار الموسمية الهادرة، والمياه الجوفية والأمطار. وقد بلغت استخدامات المياه بين القطاعات المختلفة في العام 2006 96.2% للزراعة من المياه السطحية اساسا ، 3.5% للإستهلاك المنزلي و 0.3% للصناعة.

- المياه الجوفية

تستخدم المياه الجوفية في مناطق محدودة وخصوصا في امدادات المحليات . واستهلاك المياه الجوفية في مقابلة الطلب المتزايد يتم بطريقة غير مخططة، حيث يتعرض استخدام المياه الجوفية الى استنزاف وتدهور في نوعية وجودة المياه .

- الأمطار

انخفض الحجم الذي يتلقاه السودان من الأمطار السنوية بسبب انفصال جنوب السودان من نحو 1060 مليار متر مكعب قبل الانفصال في عام 2011 الى نحو 442 مليار متر مكعب بعد الانفصال. وتتنوع كميات هطول الأمطار وتوزيعها، مع انخفاض هذه الكميات من جنوب البلاد الى شمالها، حيث يبدأ الموسم المطري من يونيو الى سبتمبر ويصل إلى قمته في اغسطس . ولا يستطيع السودان السيطرة بشكل واسع على مياه تلك الأمطار والفيضانات التي تنجم عنها او تنميتها. ويعتبر ما تم انجازه في هذا المجال متواضعا وضيئلا للغاية. فبالرغم من ان السودان يمارس عملية حصاد المياه من فترات قديمة إلا انها تنم في

مساحات محدودة . وتستخدم مياه الأمطار بدون حصاد للمياه فى زراعة 30 مليون فدان من الدخن والذرة تقريبا للإستهلاك المحلى والصادر من الزراعة المطرية التقليدية والآلية.

وقد قدرت الأستراتيجية القومية للتنمية (2007-2031) الطلب المستقبلي لموارد المياه بنحو 59.2 مليار متر مكعب، وهي تشمل الإحتياجات المائية للرى بنحو 42.5 مليار متر مكعب ، والاحتياجات للإنسان والحيوان والصناعة بنحو 10.1 مليار متر مكعب، كما قدر فاقد المياه بواسطة التبخر بنحو 6.6 مليار متر مكعب فى مشروعات الرى القائمة والمقترحة (سياسات واستراتيجيات السودان لإدارة موارد مياه الرى 2007).

2-3 سمات مؤسسات المياه – الطاقة – الغذاء ذات الصلة بالعلاقات المتداخلة الحرجة فى السودان

تشمل مجالات ارتباط المياه – الطاقة – الغذاء الرئيسة فى السودان ما يلي:

- تنمية وتوزيع واستخدامات وأمن موارد المياه
- انتاج وتوزيع وأمن الطاقة
- استخدامات الاراضى فى الزراعة وانتاج الغذاء والأمن الغذائي
- حماية البيئة
- التنمية المستدامة (شاملة تنفيذ اهداف التنمية المستدامة 2015-2030 وتخفيف آثار المناخ وتنفيذ برامج الموائمة المتكاملة مع المناخ)

مؤسسات القطاع الرئيسى فى السودان ذات الصلة بترابطات المياه والطاقة والغذاء هى وزارة الموارد المائية والكهرباء والرى، وزارة الزراعة والغابات ووزارة النفط، الغاز والمعادن. وهذه الوزارات مدعومة بمؤسسات اخرى تشمل مشروعات الزراعة فى القطاع العام ومراكز البحوث والمجالس القومية، اهمها مركز بحوث الهيدروليكية، هيئة البحوث الزراعية، المجلس الأعلى للبيئة والموارد الطبيعية، المجلس القومى للموارد المائية، وزارة المالية والتخطيط الإقتصادى، وزارات الزراعة والثروة الحيوانية والتخطيط العمرانى والمالية الولائية.

وتساهم المنظمات العالمية ايضا فى أنشطة قطاعات المياه والطاقة والزراعة واهمها منظمة الزراعة والأغذية العالمية، وصندوق التنمية الزراعية، وبرنامج الطعام العالمى، وبرنامج الأمم المتحدة للبيئة، وبرنامج الأمم المتحدة للإنماء .

وتعاني الموارد المائية فى السودان رغم توفرها من ضغوطات مختلفة من بينها تسارع النمو السكاني والتغيرات المناخية. وبالنسبة للسكان يتوقع أن يتضاعف العدد الكلي للسكان بحلول عام 2050 عن الوضع الحالي الذى يبلغ 40.5 مليون نسمة، بينما يتمثل أثر تغير المناخ فى التأثير السلبى لأرتفاع درجات الحرارة عالمياً على القطاع الزراعي، خاصة قطاع الزراعة الذى يعتمد على الأمطار، وهو القطاع الذى يعتمد عليه نحو 60% من سكان الريف فى عملهم وسبل معيشتهم. ويؤثر تغير المناخ أيضاً على النظام البيئى والتنوع البيولوجي وعلى مصادر المياه وإنتاج واستهلاك الطاقة. كما يؤثر أيضاً على ارتفاع مستوى عدم اليقين وزيادة المخاطر المرتبطة بالمياه مثل تقارب فترات الجفاف والفيضانات علماً بأن الطلب للمياه للزراعة عادة يرتفع بأرتفاع درجات الحرارة.

1-3-2 الغذاء

يتمتع السودان في مجال الغذاء بالاكتفاء الذاتي في محصولي الذرة الرفيعة والدخل، واللذان يعتبران مصدرا غذاء لغالبية أهل السودان. إلا أن السودان يعاني من نقص في سلع السكر والزيوت والقمح الذي يعتمد عليه سكان المدن كغذاء رئيسي. وقد بلغت واردات القمح 1.652 مليون طن في عام 2016 ، تمثل نحو 75% من حجم الطلب لهذه السلعة . ولتخفيف أثر التضخم الناتج من تدهور قيمة العملة السودانية مقابل الدولار الأمريكي ، لجأت الحكومة الى دعم واردات القمح بما يعادل نحو 20% من تكلفة الاستيراد.

2-3-2 الطاقة

تأثر أمن الطاقة بشكل كبير بانفصال الجنوب في عام 2011 كما تأثرت كل مكونات الاقتصاد الكلي في السودان. فقد أدى الانفصال الى ضعف أمن الطاقة الذي يعتمد على البترول مما حدا بالحكومة السودانية إلى أن تلجأ إلى استيراد جزء كبير من الطاقة الكهربائية (ما يقرب من نحو 4% من حجم الطلب) من إثيوبيا بالإضافة الى إقامة منشآت طاقة هيدروليكية باستثمارات أجنبية.

ويعتبر الحصول على الطاقة الحديثة محددًا في السودان. لذا يعتمد غالبية السكان على طاقة الكتلة الحيوية لمقابلة الطلب المتنامي. فحطب الوقود والفحم المنتج منه يمثلان نحو 75% من الطلب للطاقة في الريف. أما بالنسبة للقطن ككل فقد قدرت نسبة السكان الذين يستفيدون من الخط القومي للكهرباء بنحو 38.5% فقط. وهذه النسبة هي لكل السودان إلا أنها تختلف في المدن عن الريف، حيث تبلغ هذه النسبة في المدن 62% بينما تبلغ في الريف 22%.

يعتمد توليد الطاقة في السودان في غالبيته على الطاقة الهيدروليكية. وتبلغ السعة الحالية للقوة الهيدروليكية والحرارية للمنشآت القائمة نحو 1585 ميغاوات و1400 ميغاوات على التوالي. ويبلغ حجم التوليد الكهربائي نحو 11848 جيجا وات/ساعة في عام 2014 ، منها 75% من القوة الكهروبيئية المائية. وقد بلغ استهلاك الفرد من الكهرباء في عام 2014 نحو 140 كيلووات/ساعة وهو يقل كثيرا عن متوسط الدول الافريقية الذي يبلغ نحو 500 كيلووات/ساعة في المتوسط وعن المتوسط العالمي الذي يزيد عن 3125 كيلووات/ساعة.

3- قضايا الترابط

يعتبر قطاع المياه في السودان العامل المفتاحي في التدخلات الحكومية لبناء وتقوية ترابط المياه والطاقة والغذاء، وذلك لأن تمكين صمود قطاع المياه يعني التنسيق والتكامل بين نشاطات وخطط القطاعات الأخرى بما في ذلك قطاعي الزراعة والطاقة لأن كل منهما يعتمد على ويؤثر في موارد المياه. لذا فإن موارد المياه تحتاج لأن ترتبط مع خطط واستراتيجيات تلك القطاعات.

1-3 أهداف تقييم ترابط المياه والطاقة والغذاء في السودان

فى ضوء ما تقدم من قصور فى أمن المياه والطاقة والغذاء يصيح من الضروري رفع كفاءة استغلال الموارد عن طريق وضع اعتبار شامل للترابط بين هذه القطاعات الثلاثة للتخلص من أثار العوامل الخارجية السالبة والدفع بعوامل التنمية المستدامة للأمام وتقويتها.

وترتبط قطاعات المياه والطاقة والغذاء ارتباطاً لا فكاك منه، وهو ما يعنيه مفهوم الترابط فى هذه الدراسة، أى أنه توجد حاجة ماسة للأبعاد عن المنهجية القطاعية فى وضع السياسات والخطط وتنفيذها وتبني منهجية الترابط والتفاعل بين هذه القطاعات الثلاثة مع الأخذ فى الاعتبار التكامل والمقايضات الناتجة عن مبدأ التنازل عن ميزة من أجل الحصول على ميزة أخرى وهو ما يرتبط بإدارة هذه الموارد.

بناء على ما تقدم هدفت دراسة تقييم ترابط المياه والطاقة والغذاء فى السودان الى وضع خارطة طريق للسودان لوضع الاستراتيجيات والخطط وتنفيذها فى مسار واحد فى إطار الترابط القومى وفى إطار تصور اقليمى. ولتحقيق هذا الهدف الشامل تم وضع الاهداف المحددة التالية:

- التعرف على أهم أوجه الترابط والتكامل الممكن والفرص المتاحة لترابط القطاعات ذات الأهمية الخاصة للسودان.
- التعرف على مدى توفر الموارد الحالية والمستقبلية ومستوى استهلاكها وكفاءة استغلالها ومدى استقلاليتها.
- التعرف على اسبقيات موضوعات الترابط فى السودان ومدى التكامل بين القطاعات موضوع الدراسة فى تخطيط المياه والطاقة والغذاء، والتحديات المرتبطة بالتكامل الأفقى والرأسى.
- تقييم الاستراتيجيات القومية والسياسات والخطط المستقبلية ومستوى الاداء والمخاطر من منظور منهجية الترابط.
- وضع خارطة توضيحية لهياكل المؤسسات والأجهزة الإدارية والتنفيذية لقطاعات المياه والطاقة والغذاء وعلاقتها بمنهجية الترابط.
- طرح توصيات بشأن وضع دليل لكيفية تبنى منهجية ترابط المياه والطاقة والغذاء على أن تشمل على آلية تنظيم المؤسسات القائمة لتتنغم مع وتنظم مع السياسات والخطط الاستراتيجية القومية.
- التوصية بأقامة مشروعات ممكنة وتجريبية كنماذج لتطبيق منهجية الترابط.
- التعرف على امكانية فرص اقامة مشروعات اقليمية فى إطارمبادرة حوض النيل الشرقى لدعم حوارالترابط الأقليمى والتخطيط المتكامل لدول المنطقة.

4- التقييم الكلي- التحديات والفرص والحلول الممكنة

1-4 التحديات

ترتبط المعوقات الأساسية لأمن المياه والطاقة والغذاء فى السودان بانخفاض قدرة الهياكل المؤسسية والحوكمة (تدني تنمية البنية التحتية وانخفاض مستوى الأمن والنزاعات والفقر وسوء إدارة الموارد لمقابلة الطلب المتنامى للطعام). وقد عطلت هذه المعوقات اتخاذ القرارات الوقتية لتنمية وادارة وصيانة أنشطة قطاعات المياه والطاقة والغذاء. وتتلخص أهم التحديات بشأن الموارد فى السودان فى عدم حصول سكان الريف على الطاقة الحديثة واعتمادهم بشكل كلي على حطب الوقود والفحم. وقد نتج عن ذلك التصحر وزيادة تدهور التربة والضغط على الموارد المائية وتدني إنتاج المحاصيل وانخفاض مستويات الأمن الغذائي وتقليل امكانات انتاج الطاقة الحيوية. وعموما تعاني البلاد من نقص فى الغذاء خاصة فى محصول القمح .

والمطلوب هو تقديم برامج وخطط تساعد على زيادة تنفيذ وتطبيق اللوائح الحكومية وخلق بيئة جاذبة للإستثمار المباشر لتسريع حل كثير من القضايا المتعلقة بالمياه والطاقة والغذاء .

وعليه فإن تحقيق الأمن المائي سيساعد على حل نزاعات المياه بزيادة تخزين المياه فى المناطق المتأثرة بالجفاف وتوسيع الخدمات العامة لإمداد مياه شرب الأمن وخدمات الصحة العامة والتي تؤدي إلى حل قضايا سوء استخدام موارد المياه المتوفرة وهدرها بصورة كبيرة كما أن زيادة الوصول الى الطاقة سيؤثر ايجابيا على أمن المياه وينشئ فرصا لتقوية قدرات سكان الريف المستقلة للحصول على موارد مياه آمنة .

وزيادة الطلب على الطاقة بسبب زيادة خدمات تغطية المياه يمكن تأمينها بادخال نظم وموارد الطاقة المتجددة والوقود الحيوى المستدام المصحوب بنظم وتقانات حصاد مياه. وعلى سبيل المثال فإن انتاج قصب السكر يقدم كميات من الكتلة الحيوية لتشغيل غلايات تنقية السكر. وتتحول الطاقة المنتجة الى كهرباء لمقابلة الطلب الذاتى لمصانع السكر وامداد الفائض الى الشبكة القومية. ولكن يعيب ذلك ان تبريد المياه يلوث مياه الانهار المتاخمة كما ان حصاد القصب يتسبب فى تلوث البيئة المحيطة نتيجة الحرائق التى تضرم لتسهيل عملية سكب القصب .

4-2 التعاون عبر حدود الاقطار

يتشارك السودان مع عدد من الدول المجاورة فى موارد مائية سطحية وجوفية. والتعاون بين السودان ومصر واثيوبيا فى جبهة نهر النيل الازرق كان دائما قويا ويتم تقويته الآن نتيجة قيام سد النهضة الإثيوبي . وباكمال بناء سد النهضة ستنشأ فوائد مشتركة ومتبادلة تتطلب من كل شريك ان يكون مستعدا للدخول فى مشاريع مشتركة. وقد توقف التعاون بين السودان ودول مبادرة حوض النيل بسبب معارضة السودان ومصر للشرط الذى يحصر حق السيطرة على ادارة الموارد المائية المشتركة لكل الدول الموقعة على الاتفاقية. والتعاون بين السودان وليبيا ومصر فى حوض المياه الجوفية المشتركة مازال فى بداياته المبكرة.

4-3 مقترحات لمشروعات استثمارية فى نطاق ترابط المياه والطاقة والغذاء

4-3-1 البرامج الحوارية للتفاوض

اقترحت الدراسة ثلاثة برامج حوارية للتفاوض هي:

1. إنشاء منصة قومية لترابط قطاعات المياه والطاقة والغذاء

يهدف هذا المشروع الى إنشاء منصة قومية خاصة بترابط قطاعات المياه والطاقة والغذاء والقطاعات الاخرى، وذلك بهدف إعادة تنظيم البنية المؤسسية لتخطيط وادارة وتنفيذ برامج ومشروعات قطاع المياه والطاقة والغذاء بطريقة متكاملة. وتقدر تكلفة المشروع بنحو 1.5 مليون دولار امريكى لإعادة التنظيم الهيكلى و لرفع القدرات على مدى عامين.

2. التفاوض بشأن تنظيم ترابط المياه والطاقة والغذاء بمشروع الجزيرة

يهدف هذا المشروع الى الوصول الى اتفاق بين المزارعين والحكومة فى تأهيل مشروع الجزيرة والاستفادة الكاملة من موارد المياه والطاقة لانتاج الغذاء والمحاصيل النقدية بالمشروع. وتقدر تكلفة المشروع بنحو 1.8 مليون دولار امريكى لمدة عامين.

3. اتفاقية الحدود المشتركة بين السودان وليبيا ومصر وتشاد حول حوض المياه الجوفية بغرب السودان

يهدف هذا المشروع الى تفعيل التحاور مع دول الجوار للوصول الى صيغة قانونية ومعادلة فنية وادارية لادارة موارد المياه الجوفية المشتركة بين الدول المجاورة فى الحوض النوبى . وتقدر تكلفة المشروع بنحو 1.5 مليون دولار امريكى.

2-3-4 المشروعات الاستثمارية المقترحة

كما اقترحت الدراسة عددا من المشروعات الإستثمارية هي:

1. إعادة الاستقرار للمتأثرين ببناء سد مروى

يهدف هذا المشروع الى توفير المعونات الزراعية التى تساعد على استقرار المتأثرين ببناء سد مروى فى قرى الحامداب وامرى الجديدة فى مساحة 29 الف فدان و68 الف فدان على التوالى. وتقدر تكلفة المشروع بنحو 1.5 مليون دولار امريكى والجهة المسؤولة عن ادارة المشروع هي وزارة الزراعة الولاية.

2. حصاد المياه بولاية النيل الازرق

يهدف هذا المشروع الى اقامة السدود والحفائر للاستفادة من مياه الامطار والوديان الجارية بالولاية فى زراعة المحاصيل الغذائية والنقدية وتاهيل المراعى والغابات. وتقدر تكلفة المشروع بنحو 600 الف دولار امريكى .

3. حصاد المياه بولاية النيل الابيض

يهدف هذا المشروع الى اقامة السدود والحفائر للاستفادة من مياه الامطار والوديان الجارية بالولاية فى زراعة المحاصيل الغذائية والنقدية وتاهيل المراعى والغابات. وتقدر تكلفة المشروع بنحو 800 الف دولار امريكى .

4. توزيع حصة مياه خور ابو حبل بين الولايات المشاركة

يهدف هذا المشروع الى ادارة موارد مياه خور ابو حبل بطريقة متوازنة وعادلة لفائدة صغار المنتجين فى الولايات الثلاثة. وتقدر تكلفة المشروع بنحو 200 الف دولار امريكى.

5. مشروع تنمية صيد الاسماك لصغار المنتجين بخزان الرصيرص

يهدف هذا المشروع الى تاهيل صغار الصيادين بمنطقة مستودع خزان الرصيرص وادارته الراشدة لزيادة انتاج الاسماك وتحسين الخدمات التسويقية لصغار الصيادين. وتقدر تكلفة المشروع بنحو 200 الف دولار امريكى.

6. الطاقة الشمسية للري والإنارة بولايتي دارفور وشمال كردفان

يهدف هذا المشروع الى ادخال الطاقة الشمسية بولايتي دارفور وكردفان لتوليد الطاقة الشمسية من طلبات الري وللإنارة . وتقدر تكلفة المشروع بنحو 300 الف دولار امريكى .

7. التأقلم مع التغير المناخى فى المناطق الريفية النائية

يهدف هذا المشروع الى دعم قدرات المرأة على الصمود وتحسين المستويات التغذوية واستخدام الطاقة الشمسية. وتقدر تكلفة المشروع بنحو 300 الف دولار امريكى .

8. تحسين سبل كسب العيش لسكان الريف بولايات دارفور

يهدف هذا المشروع الى تأمين الغذاء وتخفيض حدة الفقر وزيادة القدرة على الصمود فى مواجهة صدمات تغير المناخ وغيره وتحسين سبل كسب العيش. وتقدر تكلفة المشروع بنحو 6 مليون دولار امريكى تشارك فيها مجموعة من المنظمات العالمية والعربية بالاضافة الى حكومة السودان.

1 INTRODUCTION

1.1 Background

Based on the interest expressed by the Sudanese Ministry of Water Resources, Electricity and Irrigation, the Nexus Regional Dialogue in the MENA Region³ took the initiative to develop a Nexus Assessment Study for Sudan in collaboration with the Arab Organization for Agricultural Development (AOAD). The study was carried out by Humboldt University in Berlin, Germany, the International Food Policy Research Institute (IFPRI) and the University of Khartoum in Sudan. The views of different experts and stakeholders were taken into consideration in this study, through organizing a national dialogue on WEF Nexus in Sudan as well as a validation workshop, where the main findings and recommendations of the study were presented and discussed.

This report presents the main findings of the Nexus assessment study for Sudan. It identified Water-Energy-Food Nexus priority issues in Sudan, suggested operational guidance to align national strategies, policies and implementation plans within a national Nexus framework, identified opportunities to apply the Nexus approach, including institutional settings and capacity building needs, and suggested a series of Water-Energy-Food Nexus projects in Sudan.

The water-food-energy-climate Nexus was first discussed at the World Economic Forum in Davos in 2011. The book *Water Security: The Water-Food-Energy-Climate Nexus* (Waughray, 2011) is based upon this conference. In November 2011, the German government held a global conference on the Food, Water and Energy Nexus. It resulted in a growing recognition that a movement is needed away from a sector-by-sector approach to policy, science and practice towards a more interlinked approach (Hoff, 2011; Dodds and Bartram, 2016).

The added value of a Nexus approach is that it provides a cross-sector and dynamic perspective and helps us to better understand the complex and dynamic interrelationships between water, energy and food, so that we might manage and use these limited resources more sustainably (FAO, 2014). The concept also helps us think about how decisions made in one sector might impact other sectors. Greater anticipation of and insights on potential trade-offs and synergies supports the improved design, appraisal and prioritization of interventions.

The Nexus approach, unlike the prevailing sector-oriented approach, emphasizes building integrated cross-sector synergies and perspectives, acknowledging the integrative nature of the three sectors as portrayed in Figure 1. This allows to strengthen processes aimed at meeting growing water, energy and food security demands in a sustainable way. The Nexus approach, furthermore, supports tackling key global challenges such as climate change and the increasing degradation of ecosystems and their services in line with achieving the Sustainable Development Goals.

³ The Nexus Regional Dialogue in the MENA Region is one of several regional dialogues of the Nexus Dialogue Programme, co-funded by the EU and BMZ, aiming at strengthening the process of meeting increasing water, energy and food security demands in a sustainable way, through adopting the Nexus approach. See also: <https://www.nexus-dialogue-programme.eu/regional-dialogues/mena/>

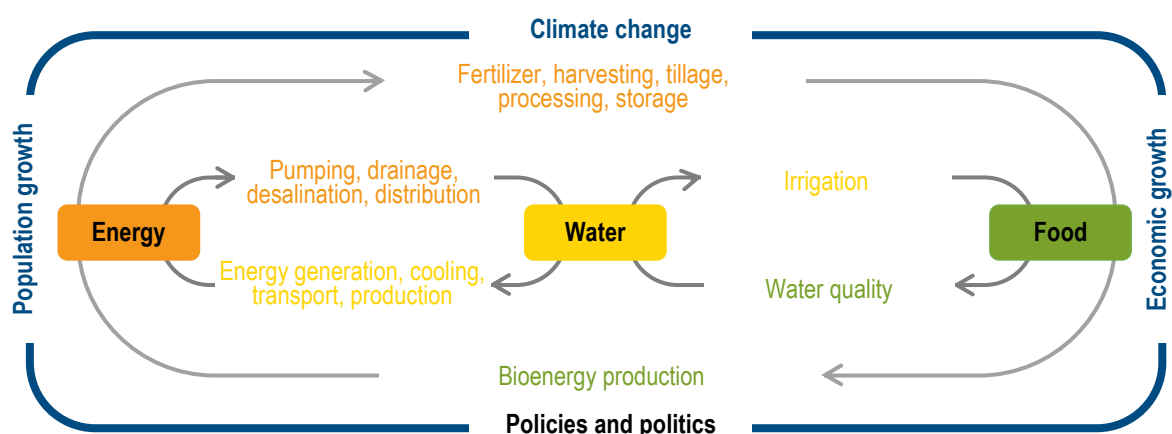


Figure 1: The interplay between food, water and energy and its main drivers

Source: Siddig (2017)

1.2 Resources and Human Security in Sudan

Despite the abundance of various natural resources related to water, energy and food, Sudan is challenged by unstable food production (below potential) and growing food demand driven by increasing population growth. Changing climate conditions, unstable policies and existing, but under-developed coordination across the water, energy and food sectors and, in general, across key government agencies are key drivers behind the mismanagement of resources related to WEF Nexus sectors in Sudan.

Box 1: Water sector in Sudan and future perspectives

Sudan has ample resources of water for energy generation and sustainable food production. The amount of water supplied by the River Nile and its tributaries and the seasonal streams totals to 30 billion cubic meters annually (Table 1) plus 442 billion cubic meters annually from rains.

Box Table 1: Sources of Water in Sudan

Source	Amount (billion cubic meters)
Surface water	6
River Nile and Tributaries	20
Renewable ground water	4
Total	30

Source: Abdalla et al (2018).

However, the mismanagement of these resources puts the human security situation at risk. The WEF issue hinges upon the existing situation of water and energy availability, distribution and uses for food production. The water and energy supply allocated to meet the social needs of the population – especially the supply of inputs for food crop production, the supply of drinking water, the provision of fuel for transportation and for marketing services – is often either unstable or in shortage.

WEF resources in Sudan are under pressure due to population growth and climate change among many other factors. Population is projected to double by 2050 from a present population of 40.5 million, while the increase in global temperature is expected to negatively affect the agricultural sector, especially the rainfed subsector that employs and supports 60% of the rural population (AfDB, 2016).

Importantly, about 80% of the water resources of Sudan are derived from outside its boundaries – including both surface and groundwater resources (Abdalla, 2018). Therefore, water security in Sudan is always linked to activities

and regulations at a larger, regional scale, and particularly to the Nile Basin Initiative and investments in upstream countries, such as Ethiopia or South Sudan.

Thus, several factors influence the regular supplies of irrigation water from dams along the River Nile and its tributaries. The 1959 Nile Agreement between Sudan and Egypt, the tradeoff between opening dams for irrigation and closing dams for hydropower generation, and the high cost of digging new canals and maintaining existing ones in the large irrigated schemes combine to place a heavy load on the national government budget, creating a critical water situation and jeopardizing future irrigation plans and food production in Sudan.

The issue of water scarcity and the management of water resources in Sudan are highlighted in the 25-Year Development Strategy (2007-2031) and consequent Five-Year Plan of the Ministry of Water Resources, Energy and Irrigation (MWREI). These plans aim at increasing the supply of water resources from different sources to meet the rising demand for water for agriculture, human and animal drinking water and for other uses (such as domestic services and industrial needs). The MWREI plans stipulate the rising demand in water for the period 2015-2050 as follows:

Box Table 2: Water demand projections up to 2050 (billion meters³/year)

Year	Irrigation	Humans	Animals and others	Total
2015	17.5	0.4	1.3	19.2
2025	27.1	1.1	3.9	32.1
2035	32.6	1.9	5.1	39.6
2050	40.3	2.5	5.3	48.1

Source: Ministry of Water Resources, Electricity and Irrigation (2018).

Box Table 3: Proposed future irrigated projects in Sudan

Scheme	Area (feddans)
Blue Nile System	592,500
Rahad Phase 1	300,000
Rahad Phase 2	202,500
Rahad Phase 3	90,000
White Nile System	242,500
White Nile Sugar	10,000
Government Pumps	187,500
Private Pumps	45,000
Atbara System	750,000
Setit	1,500,000
Main Nile System	750,000
Al Hawad	750,000
Total	5,420,000

Source: Ministry of Water Resources, Electricity and Irrigation (2018)

The strategic objectives of MWREI are based on a sector vision that disregards the demands and objectives of the other sectors using water resources. In this sense, MWREI ignores one basic principle of the WEF Nexus approach, which requires the integration of the objectives and activities of all related sectors to achieve sustainable development of the society. However, the sustainable development, management and use of the water resources depend on a Nexus approach that takes into consideration the balance of demands of all sectors.

Box 2: Energy sector and future perspectives in Sudan

Sudan has a variety of energy sources and uses. Key sources include electricity, fossil, renewable and biomass energy sources. However, few Sudanese have access to clean and modern energy sources. Traditional biomass provides for most of the energy needs of the local population, especially those who live in the countryside with no access to electricity. Fuel wood and charcoal provide for about 75% of the country's energy needs for cooking. By 2016, only about 38.5% of the total population was connected to the national grid. Access to electricity is high in urban areas, reaching about 62%, but remains extremely low in rural areas, at about 22% in 2016.

The total energy supply of Sudan reached 13.1 million tons of oil equivalent (TOE) in 2015 (NERC). Biomass contributed 54%, petroleum supplied 40% and hydropower supplied 6.0%. The hydropower electricity generation installed capacity is about 1,585 MW (total potential is 4,176 MW) and the thermal power electricity generation installed capacity is 1,400 MW.

Hydropower and thermal power generation dominate the overall sources of electricity supply in Sudan. According to available data, total electricity generation was estimated at 11,848 GW in 2015, of which about 55.8% was met by hydropower (UNEP, 2017 quoted in Sudan Nexus Profile, 2018). Per-capita electricity consumption was 190 KWh in 2014, which is below the average per-capita consumption of about 500 KWh per year for all African countries and a world average of 3,125 KWh per year (NDP and LAS, 2018).

The electricity system is composed of the national grid, which supplies limited zones – mainly the central, north and eastern Sudan – and the off-grid system composed of isolated small-scale thermal power plants that supply remote cities and regions. Solar and wind energy are in their early stages. Regions in Sudan that do not have access to electricity from the national grid or the isolated grids rely on small diesel-fired generators for power. Major groups that consume electricity in Sudan are the residential and services sectors, which account for around 80% of the total electricity consumed (mainly to satisfy lighting and cooling demands).

The separation of South Sudan led to a decline in oil production by Sudan of 75% (NDP and LAS, 2018). In response, the government of Sudan has been exploring new concessions. The Ministry of Oil and Gas estimates Sudan's reserve to be around 514,300 billion barrels (AgWA-FAO, 2015). Most of the producing oil fields are distributed in areas close to White Nile state. Sudan produces 90% of its benzene and exports 10%, which is used for payment of imported electricity from Ethiopia. On the other hand, Sudan imports its entire diesel required for transportation purposes.

As the country's oil-dependent energy security was severely weakened after 2011, the government opted for plans to import energy from Ethiopia and to construct new hydropower plants with foreign investments. The effectiveness of these alternative measures is contested, however. Key government strategies for power-sector development are to: utilize the renewable energy resources potential in Sudan to make electric energy available all over the country; achieve a competitive price of energy from renewable sources; diversify energy supply sources and ensure energy security; support the national economy by technology and knowledge transfer, building capacities and promoting local renewable energy industry; and provide access to electric energy supply to rural areas far from the national or the isolated grids for which the grid extension is not a feasible solution.

Targeted fields in the energy sector

The 25-Year Development Strategy visualized bridging the deficit by building more dams, increasing thermal power generation units, increasing dependence on renewable energy and increasing imports of electricity from Ethiopia. According to the Ministry of Water Resources, Irrigation and Electricity (2018), there are plans to:

- Provide electric energy coverage to all parts of Sudan by 2031.
- Increase electrification rate from 19% in 2007 up to 35% in 2017, to be increased furthermore.
- Erect 1,100,000 solar home systems (SHS) in rural areas.
- The Sudanese Electrical Distribution Company (SEDC) 2017 plan aims to install 10-14 thousand agricultural solar pumps to irrigate 20,000 acres in each state. The plan also aims to provide lighting to 300,000 houses and provide water for humans and livestock over the course of five years.

Goals in the energy sector, including electricity and thermal fuel energy goals, are primarily aimed at increasing supply for household consumption. Energy allocated to supplying water for food production and for mechanized operations for food production is minimal, not exceeding 7% in the case of the former and 1.5% in the case of the latter. A Nexus approach requires improved energy efficiency and management.

Box 3: Agricultural and food sector in Sudan and future perspectives

Agriculture contributed 34% of GDP (11.7% crops and 18.1% livestock) on average during 2000-2018. Out of the total approved foreign investments (more than USD 8 billion) in Sudan, USD 206 million related to agriculture. Agricultural investment accounted for around 2-3% of total investment pledges during 2000-2013.

During 2000-2016, agricultural exports amounted to USD 725 million (13% of total exports) while agricultural imports amounted to USD 1,234 million (17% of total imports). In 2016, the exports went up to USD 750 million and imports increased to USD 1,776 million. The sector exports a diversity of crops in the form of raw materials including cotton, sesame, gum Arabic, groundnuts, sometimes sorghum, hibiscus and melon seeds and livestock (mainly sheep). Sudan exports of sheep reached around 6-7 million heads in 2017-2018. Agriculture received 14% of total commercial bank credit during 2000-2014, while exports credit dropped from 19% to less than 5%, which might have been the reason for negative performance of the agricultural exports of Sudan.

The total cultivated area ranges between 17-21 million hectares (40 and 50 million feddans). The total area under the irrigated schemes is estimated at 2.02 million hectares (4.8 million feddans), of which less than 50% are cultivated. The total area under the mechanized rainfed schemes is estimated at more than 8.4 million hectares (20 million feddans) while that under the traditional rainfed agriculture system is also estimated at around 8 million hectares (20 million feddans).

Sudan has 107 million heads of livestock (cattle, sheep, goats and camels) living in the rural rainfed areas that require water and pasture. Livestock resources contribute about 700,000 tons of meat, including 300,000 tons of cattle meat, 200,000 tons of goat meat and 160,000 tons of sheep meat (Abdeen, 2018). However, the per-capita consumption of meat is estimated at 20 kg per year, lower than the 30 kg average for developing countries. Sudan produces 7 million tons of milk; 72% from cattle, 20% from goats, 7% from sheep and 1% from camels. Per-capita consumption of milk is estimated at 19 liters per year, lower than 50-liter average for developing countries. It is of the utmost importance that the WEF Nexus considers the sustainable development of the livestock sector in Sudan through the provision of adequate access to livestock water sources, for example, through water harvesting and other types of technologies.

Fish resources are available in rivers, manmade lakes and along the Red Sea coast. The fish resources are estimated at 232,650 tons per year, though annual fish production dropped from 70,000 tons to 25,000 tons due to insufficient investments and inadequate utilization of inland and marine fisheries resources. The per-capita consumption of fish is estimated at 1.3 kg per year. The recent production of pond fish increased the volume of fish from 3,560 tons in 2012 to 9,000 tons in 2016 (Abdeen, 2018).

Food production in Sudan takes place under irrigated schemes and rainfed semi-mechanized and traditional agriculture systems. Around 95% of agricultural land in Sudan is found in the drylands while 5% is found in the central clay plains. Given the unreliability of rainfall and poor management of irrigated farming, the risks to producing enough to guarantee food security in Sudan are high.

The expansion of the crop area planted and harvested has been increasing substantially during 1953/54 to 2015/16. The cultivated area increased from 5.564 million hectares, on average, during 1953/54-1955/56 to 41.274 million hectares, on average, in 2013/14-2015/15, that is by a factor of 7.4 times during this period. However, due to variation in the intensity and distribution of rainfall, a lack of access to technology and poor agricultural management, the area harvested is always less than the cultivated area. The decrease in the area harvested between the two periods indicates a worsening situation that may be related to, in addition to rainfall variability, recurrent droughts and flooding cycles.

Newly developed large-scale irrigation schemes have been the leading economic investment of Sudan, but their recent performance has been considerably below potential due to a variety of reasons, including inadequate commitments from investors and weak monitoring by government authorities. For example, of the 4.5 million feddans prepared for irrigation in 2005, only half were actually cultivated, largely because of inadequate irrigation and drainage infrastructure. Crop output declined with lower income and lower foreign currency revenues to the country. Poor maintenance of irrigation canals from accumulating silt was caused by weak institutional, technical and financial capacity of these schemes.

Opportunities to increase agricultural production in most areas of Sudan are limited due to management challenges around irrigation water. Therefore, improvement in managing available water in Sudan and in already existing irrigation schemes is crucial to meeting the food demands of the country's growing population. The irrigated sector has not responded positively to the policy orientations due to bottlenecks and structural problems of infrastructure and finance. Hence, the administration of the agricultural sector has to address management issues – especially those related to water use in the irrigated schemes.

The concept of supplementary irrigation in farming in Sudan is almost lacking. Sudan needs to increase supplementary irrigation schemes since the bulk of the agricultural production falls under rainfall and is thus exposed to the risks of climatic changes. Thus, to reduce risks and increase the productivity of land, expansion of supplementary irrigation facilities through water harvesting and the exploitation of underground and surface water is mandatory.

Sudan is self-sufficient in sorghum and millet, the two basic staple crops in rural areas, but fails to meet the supply needs of the growing urban sector for wheat. In 2016, wheat imports amounted to about 1.652 million tons. Average supply of cereals, mainly sorghum and millet, was estimated at 7.7 million tons in 2014 and was projected to increase to 12.7 million tons by 2030 while the demand was estimated at 5.7 million tons and projected to increase to less than 12 million tons during the same period. This indicates the possible opportunity for storing a surplus of sorghum for future use and/or export.

In addition to having to rely on imports of wheat, sugar and other foodstuffs, Sudan faces other challenges to food insecurity. About 68% of the people in Sudan were food insecure, 30% were deprived of food access, 40% were undernourished and 3 million were stunted and wasted children (Ministry of Health, 2013). The main causes were attributed to structural food deprivation and seasonal food shortages. The situation varies among states. The states lying along the banks of the Nile and seasonal rivers are better off than those depending on rainfall. People in conflict areas are affected more than those in areas without conflicts. The people depending on traditional rainfed livelihoods are affected more than those using technology supporting irrigation and other intensification.

Growing urbanization and inflows of refugees and internally displaced people (IDPs) into cities are major driving forces behind increased consumption, and hence, production of wheat in the irrigated sector. About 75% of domestic demand for wheat is met by imports. To mitigate the impact of inflation, due to the deterioration of the Sudanese pound against the American dollar, the government subsidizes food by about 20% of the import costs in the form of concessional exchange rates for the importers.

Targets for food security as projected in the Vision 2007-2031

- Increase the area of irrigated agricultural land from 4 million feddans to 10 million feddans
- Double the rainfed cultivated area to reach 50 million feddans

Institutional systems and arrangements

The decentralization strategy implemented by the government delineated the roles and responsibilities of the central government and the state governments in policy design and implementation. The central government is responsible for planning and the governments of states are responsible for administering and executing development activities at state and locale levels. The Local Government Act (1989 and 2003) entrusts to the localities the conservation and protection of the natural resources to ensure their sustainable use and management, especially water points. Moreover, it encourages reforestation and provides services to promote agriculture, forestry, natural resources and animal wealth.

Lack of adequate infrastructure often dampens the responsiveness of farmers and investors. The poor infrastructure – especially in transportation and energy with frequent power cuts and shortages in diesel and gasoline – results in high costs of production and transportation, which drive businesses out of the markets of some industries. Of primary concern are storage facilities used to support water, energy and food security as well as transportation and road infrastructure supporting the movement of resources.

The existing grain storage capacity of the Agricultural Bank of Sudan consists of 295 thousand metric tons of silos and 310 thousand metric tons of warehouses. The government plans to construct additional metallic silos for a total 2.024 million metric tons of storage capacity during 2017-2021. Similarly, water storage facilities are inadequate given growing water variability and climate change. Availability of water storage is directly linked to food production and energy production.

The management of road infrastructure is shared between the National Highway Authority and the state governments. The National Highway Authority is responsible for the highways that connect major cities and the state capital network while the states are responsible for networks that connect towns and rural communities and their links to the national network. The existing road network is estimated at 31,965 kilometers with recent expansion plans of 4,317 kilometers. During 2020-2030, Sudan plans to develop an additional 9,864 kilometers of roads. This reflects the importance of roads in shouldering more than 90% of the total freight of Sudan.

2 WEF INTER-LINKAGES, RISKS AND OPPORTUNITIES IN SUDAN

2.1 OVERVIEW

The critical inter-linkages – as identified by stakeholders consulted in Sudan and identified through data and an evidence-based approach – are associated with certain risks and trade-offs. These can be visualized using two basic Nexus diagrams (Figure 2 and Figure 3). The risks on the one hand, as well as the opportunities arising from innovative Nexus approaches, on the other hand, are explained in detail below.

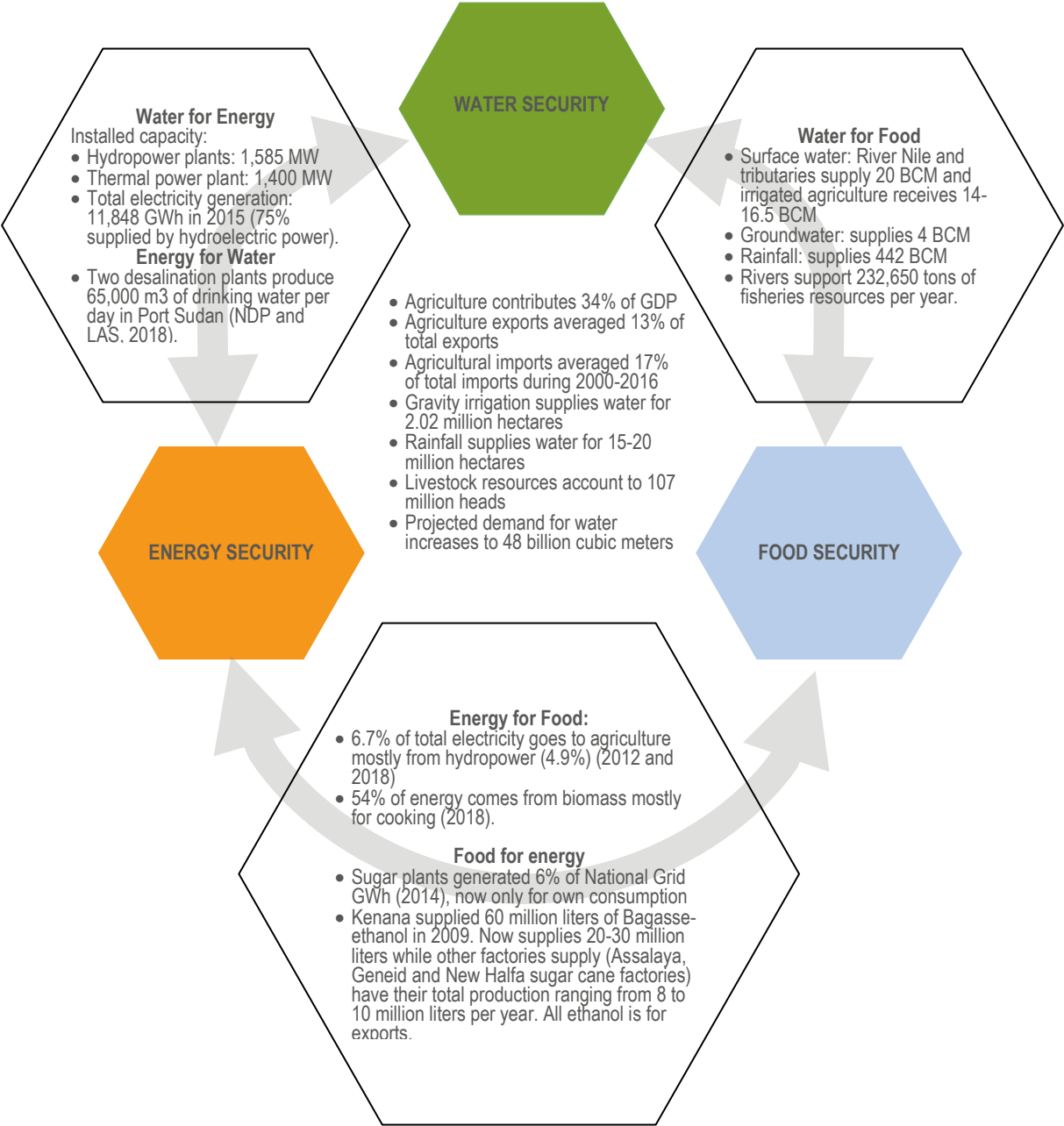


Figure 2: Mapping of the existing situation of the WEF Nexus in Sudan. Source: Authors’ compilation based on data from Abdalla et al. (2018), Rabah et al. (2016), Rabah (2018), Ministry of Agriculture and Forests (2018), Central Bank of Sudan (2017).



Figure 3: Mapping of interlinkages, trade-offs and risks

Source: Authors' compilation

2.2 Water for Food Production

Agriculture is the largest user of irrigation and rainfall in the country. It uses about 96.5% of the country's share of the River Nile water. Yet agriculture contributes only 34% of the total GDP, of which 50% is contributed by the livestock sector, which raises animals mainly in rainfed farming areas.

Key types of irrigation include:

Gravity irrigation by dams across the Blue Nile and Atbara rivers; practiced in the Gezira and New Halfa public irrigation schemes. The heavy dependence of the large irrigation schemes on gravity irrigation is at risk from increased need to retain the water in reservoirs for generating electricity for domestic use. The cost of cleaning silt from the dams and from canals often reduces water allocation to irrigated crops. **These challenges can be better addressed through WEF Nexus coordination.**

Pump-irrigated agriculture from the Nile and from surface wells is practiced in big irrigation schemes in the Northern, River Nile, White Nile, Blue Nile and Sinnar states and in the Rahad Scheme. Small pumping units also dominate production systems in the Northern and River Nile states. Pumping of irrigation depends on large imports of diesel fuel, which is always irregular or scarce. **The high cost of imported fuel and pump maintenance reduces the competitiveness of nationally produced food crops in both the domestic and foreign markets.**

Spate irrigation from the Gash and Baraka seasonal rivers comes from the Eritrean highlands carrying tremendous amounts of water and silt that flood deltas and cover large areas. The sudden flushing of these streams deprives the country from the full utilization of the flood waters, which instead replenish groundwater. A lack of preparation and programs to harness the flash floods results in the cultivation of only a relatively small portion of the potential cultivable area. In the Gash area, the cultivated area does not exceed 70,000 feddans out of the total potential of 700,000 feddans.

Overall, most water resources originate outside Sudan, depend on the prevailing climatic situation and are not managed efficiently. Sudan is currently not using its full share of Nile waters, as it withdraws only about 14-16.5 billion cubic meters out of 18 billion cubic meters due to managerial and financial constraints. The reasons for underutilizing water resources are the drastic decline in cultivated areas in the Gezira Scheme and the other public and private irrigated schemes, the high cost of maintenance of the dams and water canals, and the ongoing shortage and irregular supply of diesel fuel. This results in a relatively low contribution of the irrigated sector to total GDP. The future demand for water in Sudan is projected to reach 48 billion cubic meters as shown in Box 1 and Figure 1 above.

The dependence on rainfed food production carries risk. Variability in the intensity and distribution of rainfall, and exposure to recurrent floods and droughts can damage production. Therefore, there is a need to focus on harnessing water, such as through water harvesting techniques to increase the self-sufficiency of local communities and to promote more synergistic management of the water system.

In the rainfed areas of Sudan, water is the key limiting natural resource and often a factor generating conflict. Obtaining water in the dry season is particularly challenging for pastoralists, but also challenging for agro-pastoralists and small settled producers. Access to water is more critical than access to grazing resources. Acquiring water provisions consumes the greatest portion of time, efforts and income of rural communities in the drylands. Common water sources include water yards, *hafir* (seasonal water reserves), dams, the Nile and its tributaries, deep and shallow hand-dug wells (*edd*) and natural ponds and depressions (*wadi/khor*). The recent introduction of mobile bladder water tanks facilitates access to remote pasturelands. While water is available during the wet or rainy seasons, sources, such as ponds and natural depressions, poor quality can lead to diseases in humans and animals.

Traditional water sources are sealed off by semi-mechanized rainfed cultivation in the post-rainy season. Irrigated crops block access to rivers and Nile banks. Pastoral herders often accuse small-scale farmers of intentionally blocking access to local water sources, or purposely degrading hafirs to keep them off. Further accusations include pollution of water and burning of neighboring pastures. Water sources often encourage human settlement, making herders' access to water even more difficult.

The construction of dams created large lakes that could potentially be utilized by the fish-production industry in the country. However, the present fish catch is far below potential resources (FAO/Mamoun Behairy Center, 2016). Moreover, the widespread practice of catching immature fish may reduce the multiplication rate of fish in the lakes. Furthermore, the rapid siltation rate of the dams may close the lakes and reduce or eliminate fisheries, as is the case with the Khasm Al-Girba Dam. Desilting of dams and its timing are critical for the optimum use of these high-value food resources in Sudan (FAO/Mamoun Behairy Center, 2016).

Rising demand for food due to increased population growth along with changes in consumption patterns and irrigation water supply calls for a Nexus approach.

Box 4: Opportunities to improve planning and water-efficiency in agriculture and food production

<p style="text-align: center;">Opportunities</p> <p>to improve water- efficiency in agriculture and food production, making it more water- smart</p>	<ul style="list-style-type: none"> • Increasing efficiency in water resources harvesting and supply through optimization and rehabilitation of dam infrastructure • Giving due consideration to fish production when managing dams • Deploying water harvesting systems, where possible, for supplementary irrigation including drinking water for animals • Harnessing renewable energy potential by replacing high-cost diesel pumps with solar- and wind-driven pumps to irrigate water for food production, especially in remote areas away from the national grid • Increasing water-use efficiency and reducing the overall water demand and, accordingly, energy demand
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2.3 Water for Energy

Biomass is the dominant source of energy followed by petroleum and hydropower generation. Biomass supplied 54% of the total 13.1 million tons of oil equivalent (TOE) in 2015 (NERC, 2015) while petroleum supplied 40% and hydropower supplied 6.0 % (Figure 4).

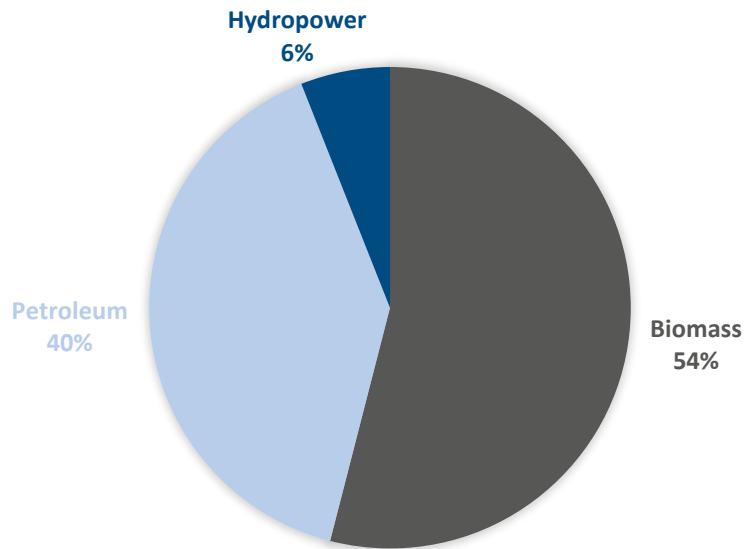


Figure 4: Sources of energy supply in Sudan

Source: National Energy Research Centre (NERC, 2015)

The household sector consumed 57% of electricity supplies while agriculture consumed only 7% (Figure 5). Electricity generation in Sudan is supplied by hydropower generation and by thermal power generation. Rosaries and Sinnar Dams on the River Blue Nile and Merowe Dam in the main River Nile supply hydropower generation in Sudan. These are renewable sources of energy.

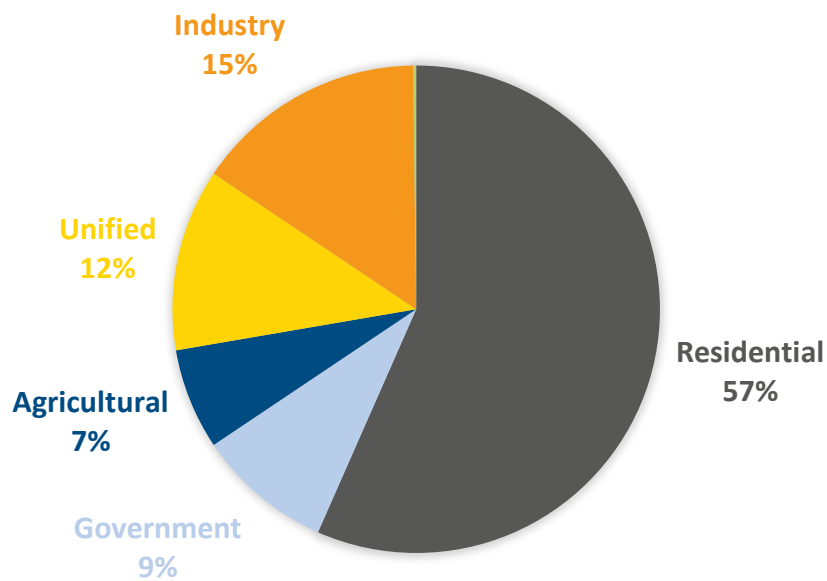


Figure 5: Electricity consumption by sector (percentage)

Source: Ministry of Water Resources, Electricity and Irrigation (MWREI), (2018)

The recent plans to build a number of hydropower generation dams on the River Nile and Setit and Upper Atbara have begun with the construction of the Merowe Dam and the Upper Atbara Dam complex. The construction and operation of Merowe Dam was associated with an installed capacity of 1,250 MW, thus doubling the hydropower generation in Sudan. The heightening of Roseires Dam by ten meters was also completed, adding a storage volume of 4 Km³ of water. The heightening was not accompanied by a new irrigated scheme and thereby allocated most of the added storage water into increasing the hydropower generation from Roseires. The construction of the Upper Atbara Dam complex was completed in 2016 with an installed capacity of four turbines with a combined capacity of 320 MW.

Despite the construction of the new dams and the heightening of the Rosaries Dam, the gap between the supply and demand for electricity has not been closed. Sudan is balancing its electricity deficits with imports from Ethiopia. However, the operation of the Grand Ethiopian Renaissance Dam (GERD) will likely change the flow regime on the Blue Nile and on the main Nile River, lowering flood peaks and increasing low flows during summer months. The regulated flow of GERD is expected to increase the electricity generation from the Roseires Dam by 28%. If the turbines at Roseires were upgraded to 400 MW, this would increase electricity production by more than 40%. The change in the flow regime from GERD would also support increased electricity generation at Merowe Dam, an increase by 10%, and would grow power generation at Sennar Dam as well. The regulated flow will also enable micro generation of electricity from irrigation canals (Ministry of Water Resources, Electricity and Irrigation, 2018).

Box 5: Opportunities to improve planning and water-efficiency in energy sector

<p>Opportunities</p> <p>to improve water-efficiency in the energy sector, making it more water-smart</p>	<ul style="list-style-type: none"> • Integrated planning of new hydropower-generation dams with current and future changes in energy producing systems in neighboring countries, especially Ethiopia • Benefit from lessons learnt from existing dams such as the Khasm Al-Girba Dam almost reaching its lifespan and from Merowe Dam with debates about its efficiency
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2.4 Energy for water production and distribution

Electricity and fossil energy constitute the two main sources of energy for water production and distribution in Sudan, which are often irregular or in shortage at peak time. Hydropower and thermal power generate electricity used in water pumps in different parts of Sudan connected to the national grid. Imported diesel fuel is used in large public corporations and private-sector pump schemes. Some of these schemes were transformed from diesel-powered pumps to electrically powered pump schemes, which helped in decreasing the cost of irrigation by almost 30%. Sudan also depends on imported diesel fuel for the production of food and fodder crops using motor pumps for supplementary irrigation. Shortage of hard currency is a large constraint, limiting the import of diesel fuel while hydropower generation is often irregular, especially during the peak irrigation period.

The prospects for introducing renewable energy sources, especially solar energy, are promising given the number of bright sunny days throughout the year. Two solar energy units, each of 5 MW, are currently being installed in Kordofan and Darfur States in Western Sudan (Ministry of Irrigation and Electric Power, 2018).

The energy policy of the State Ministry of Agriculture in the Northern State is aimed at converting agricultural diesel pumps into electric pumps. However, given the recent experience with fluctuations and shortages in the electricity supply from the national grid, the ministry has moved toward the adoption of solar pumps.

A UNDP/GEF/SEDC project is currently supplying 1,440 solar pumps in the Northern State with soft loans. The project started as a five-year pilot Solar Pump (PV) project experimenting with 28 farmers in the Northern State in 2018. Following positive results from the pilot phase, the project decided to supply 1,440 solar pumps to other farmers in the state on a soft credit basis. The technical and financial feasibility study based on data and information from more than 500 farmers in different localities of investors in the state found the program to be viable.

Foreign direct investment in irrigation now covers about one million feddan both in upper terrace areas and in dryland areas pumping groundwater. Instances where investors were involved in growing wheat and clover using sprinkler irrigation resulted in the depletion of underground water resources. Therefore, groundwater irrigation needs to be carefully assessed and monitored to avoid future groundwater depletion.

Future Plans

SEDC plans to generate electricity for home consumption and agriculture using a solar system and solar pumps in the remote areas outside of the national grid in Darfur, West and South Kordofan and the Blue Nile state. The plan aims to install 10-14 thousand agricultural solar pumps to irrigate 20,000 feddans in each state. The plan also aims to provide lighting to 300,000 houses and provide water for humans and livestock over the course of 5 years.

Efforts to make use of energy from wind are also ongoing. A map of potential areas where energy from wind can be economically generated has been developed (www.windprospecting.com). The areas of Dongola in the Northern State, Tokar in the Eastern State and Nyala in Darfur State have been selected as potential areas using a prospecting map.

2.5 Energy for Agriculture (Food)

The household sector consumes 38.4% of total energy, followed by the transport sector (31.2%), services sector (16.0%), industrial sector (13.1%), and agriculture sector (1.4%) (NERC, 2015).

Energy supplies and consumption in agriculture include the use of diesel fuel for the transportation of agricultural products and agricultural mechanization activities and the use of biomass – mainly firewood and charcoal – in cooking food. Transportation of agricultural commodities is assumed to consume between 30% and 50% of all transportation fuels in the country. As such, changes in fuel prices directly affect food prices. They add cost to consumers in Sudan and reduce the competitiveness of agricultural exports abroad.

The use of diesel fuel in agriculture in Sudan started in the 1960s when the country began crop diversification and intensification policies as part of the Gezira scheme. The demand for diesel fuel increased significantly with the policy of horizontal expansion of agriculture in the drylands under rainfed private-sector mechanized schemes in the mid-1970s. Without mechanization, the fast-horizontal expansion of the cultivated land in the heavy clay soils would not have been possible. Farm machines have revolutionized agriculture and continue to

do so today. They are employed in land preparation, seed planting, fertilizer and pesticide spraying, and harvesting as well as in sprinkler irrigation and water pumping. Assuming use of 2-3 gallons of diesel fuel per feddan for mechanization purposes, the activity requires the seasonal supply of 1-1.4 million barrels of diesel fuel (22 million feddans by 2-3 gallons equal 44-66 million gallons. One barrel is equal to approximately 50 gallons). Thus, agricultural mechanization of both irrigated and rainfed systems requires on-time supplies of one to 1.4 million barrels of diesel fuel transported and stored in remote areas in time for the planting season. Frequent shortages in the supply of imported diesel fuel result in delays in land preparation and sowing dates, the primary determinants of a successful cropping season.

Sudan encouraged the use of Liquefied Petroleum Gas (LPG) as an alternative to reduce the consumption of both kerosene and biomass. However, the daily LPG production rate of 930-1000 tons in the Khartoum refinery is far less than the demand (estimated at 269,000 tons in 2008). The import of LPG is limited by shortages of hard currency, and constraints on storage facilities and distribution capacities, which are reflected in higher costs and prices. The supply of LPG to consumers in remote areas remains costly. The absence of financing for LPG companies curtails the expansion of the gas. Moreover, the elimination of LPG subsidies in 2013 resulted in further price escalations.

Policies to control deforestation for the procurement of cooking fuel and charcoal have been ineffective. Unless affordable energy alternatives are introduced, deforestation cannot be halted. **Fehler! Verweisquelle konnte nicht gefunden werden.** presents the contribution (share) of each energy source to domestic cooking. In 2015, three quarters of total energy for cooking was sourced from firewood and only 1% from kerosene.

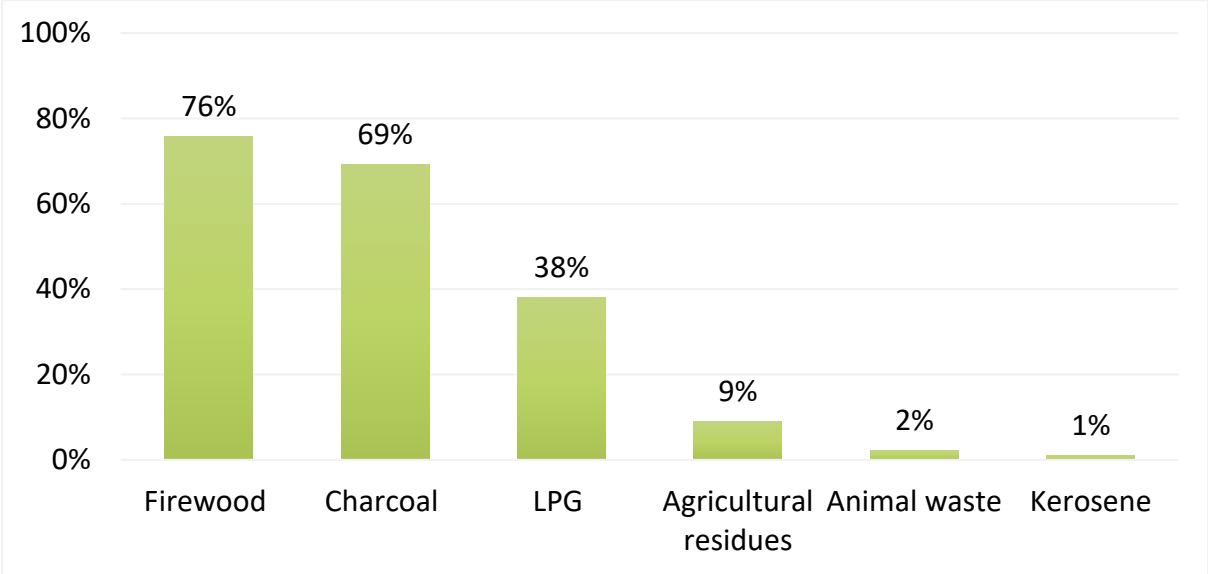


Figure 6: Share of household cooking (percentage) in the use of each energy source

Source: National Energy Research Centre (2015)

2.6 Food for Energy

Sudan has six sugar-producing factories that cultivate about 200,000 feddans and produce 700-800 thousand tons of sugar (Table 1) annually. Sugarcane production is associated with the production of bagasse, a biofuel

that can be used for multiple purposes, such as generating electricity, biofuel in the form of ethanol and licking-bricks. According to NDP and LAR (2018), biomass provides an estimated 51% of energy in Sudan. The licking-bricks are made from a mixture of salt and sugarcane residues and are largely used by the growing dairy industry in the major capital cities and towns in the country. The produced electricity is consumed by the factories and the surplus, if there is any, is linked to the national grid.

There is a tradeoff for bagasse uses between the generation of electricity and the production of ethanol and licking-bricks. Given these tradeoffs, it is proposed to first meet domestic demand for bagasse and consider ethanol production and export once these needs have been met.

Other agricultural sources that could provide biofuel/biodiesel energy at a limited scale include the wild fruits of the Heglig and the Jatropha tree. The Heglig tree grows widely in the Kordofan region while Jatropha was introduced into South Kordofan State. The problem with the Heglig tree is its sparse distribution over a large area, making collection of the fruits very costly. Jatropha trees, on the other hand, consume considerable amounts of water and are poisonous. According to feedback from the Department of Agronomy at the University of Khartoum and based on several conferences and meetings discussing this issue, the recommendation is to stop the production of Jatropha in Sudan.

The sugar industry generates its own power consumption from bagasse, a byproduct of sugarcane. Table 2 shows the installed capacity of electric power plants in the sugar industry in Sudan, which accounts for about 190 MW, equivalent to 6% of the national electric grid power. However, companies often operate below capacity. For example, due to low operation levels of the White Nile Sugar Factory, capacity has been reduced to 96 MW. Sugar factories also produce heat for sugarcane milling, evaporation and crystallization processes. If cogeneration would be installed, heat load would be reduced as the sugar mills and shredders would be electricity-driven rather than steam-driven, which would save steam for power generation (Rabah et al., 2014). More work on the cost-benefit assessment of such cogeneration is needed.

Table 1: Sugar cane cultivated area (feddans) and production (000 tons)

Factory	Area (feddans)	Production (000 tons)
Gunaid	40,000	70-90
NW Sinnar Sugar Factory	35,000	64-76
Assalaya	35,000	89
New Halfa	30,000	56-68
Kenana Sugar Company	71,400	350-470
White Nile		67-74
Total		680-840

Source: Central Bank of Sudan Annual reports (multiple issues)

Table 2: Sugar industry power plants

Factory	Year	Sugar capacity		Bagasse		Power Plant generation		
		Installed	Current	Installed	Current	MW	D/Y	GWh
		Kton	Kton	Kton	Kton			
Kenana	1981	300	307.6	1350	580	20	210	326
Sinnar	1976	70	73.1	321	138	6.5	210	33
Assalaya	1980	70	65.4	287	123	6.5	210	33
Gunaid	1962	70	73.1	321	138	6	210	30
New Halfa	1966	70	59.5	261	112	6	210	30
White Nile	2012	450	73.4	322	138	(104) 6.0	210	33
Total		980	652.1	2862	1230	(190) 96		485

Note: Bagasse/sugar ratio is 4.4; the design capacity of power plant is 104 MW

Source: Rabah et al. (2016)

3 KEY AND CROSS-SECTORAL INSTITUTIONS FOR WEF NEXUS MAINSTREAMING

This section describes the key sectoral and inter-sectoral institutions in Sudan as well as gaps and opportunities for enhanced cooperation.

The Ministry of Water Resources, Electricity and Irrigation (MWRIE), the Ministry of Agriculture and Forests (MA&F) and the Ministry of Oil, Gas and Minerals are the main ministries engaged in water, energy and food (WEF) activities in Sudan (Figure 7; see also Berga et al. 2017).

They are supported by other institutions including the Agricultural Public Schemes Managing Boards, the Hydrology Research Centre, the Agricultural Research Corporations, the High Council for Environment and Natural Resources (HCENR) and the National Council for Water Resources (NCWR). The Ministry of Finance and Economic Planning (MFNEP) is the overseeing institution for the allocation of annual general and development budgets to WEF. The State Ministries for Agriculture, Livestock and Irrigation and the State Ministries of Physical Planning and Finance are responsible for the planning and implementation of WEF at state and locality levels.

The institutions concerned with water harvesting programs, especially for small producers in agriculture, are fragmented with poor coordination, which results in ineffective policy implementation and dependency on international organizations and NGOs.

The international organizations and non-government actors provide technical support in areas related to planning and implementation of WEF in the country at the federal, state and locality levels.

The FAO, IFAD, WFP, UNEP, AOAD and UNDP provide technical and financial support to capacity building, carrying out situation analyses to inform water-related policy-making and management. The UNESCO Chair in Water Resources (UWCR-SD), founded in 1994 in Sudan, serves the Nile basin and Shared Aquifer countries in the region and contributes to international debates on water resources.

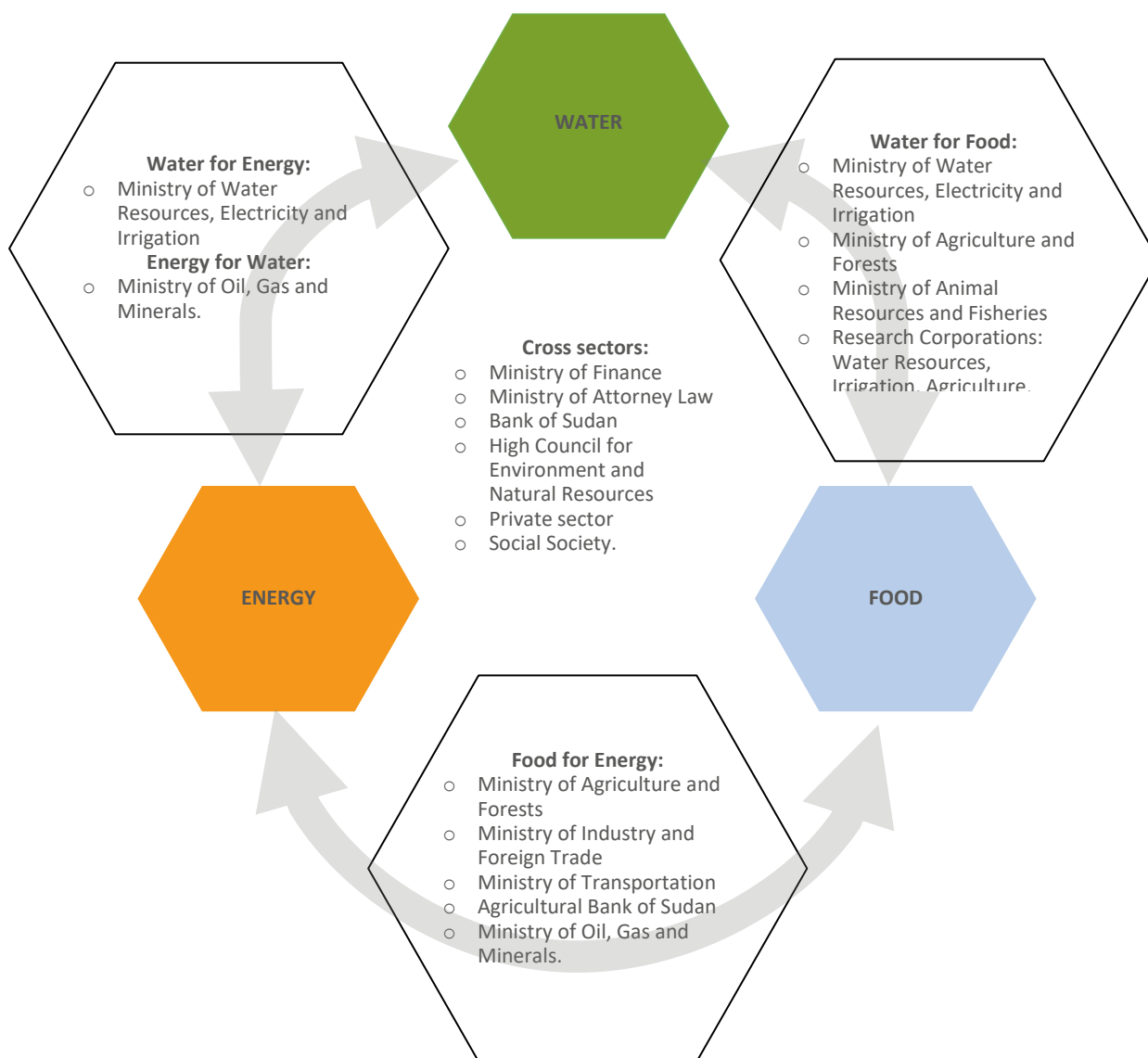


Figure 7: Sudan WEF Nexus Institutions Mapping

Source: Authors' compilation

3.1 Key WEF Institutions

The Ministry of Water Resources, Electricity and Irrigation (MWREI) is the principal ministry leading WEF sectors in Sudan. The Ministry is responsible for planning and policy formulation, as well as follow up and monitoring of programs, projects and activities in the water, electricity and irrigation sectors. The Ministry has the National Water Resources Council as an advisory body and is composed of three secretariats and affiliated units and administrations. These are the Dams Unit, the Electricity Generation and Distribution Unit and affiliated companies, and the Irrigation Unit responsible for the management of irrigation activities in the large public irrigated schemes in the country. Of specific importance, the Ministry introduced two Renewable Energy Departments, the Department of Solar Energy and the Department of Wind Energy.

Entry points for MWREI for enhanced cooperation and alignment of sector and national strategies involve, among others:

- Laying policies and general guidelines for water resources, electricity generation and irrigation.
- Carrying out baseline surveys, collecting statistics and information and evaluating studies on supply and demand for water, electricity and irrigation activities including those of solar and wind energy activities.
- Carrying out supply and demand studies for all types of energy consumption.
- Undertaking institutional capacity building of staff.
- Efficiently managing water resources, electricity generation and irrigation development and use at the federal level.
- Coordinating and providing technical supervision on dams.
- Developing federal-state level coordination for implementation and follow-up activities.
- Coordinating research on water resources development, electricity generation, solar and wind energy and irrigation.
- Transporting and distributing water resources and generated electricity.

The Ministry of Water Resources, Electricity and Irrigation is the principal government entity responsible for achieving sustainable, balanced supply and demand for water resources, electricity and power generation and irrigation needs of different agricultural farming systems in Sudan.

The Ministry of Agriculture and Forests (MOAF) is the principal government entity responsible for planning and policy formulation related to agricultural and food security development investments and activities in Sudan.

Potential entry points for MOAF for enhanced cooperation and alignment of sector and national strategies based on the ministerial mandate include, among others:

- Formulation of agricultural water management policies in irrigated schemes and the rainfed sector.
- Preparation of strategies, plans, and long-term and mid-term policies to achieve food security.
- Following up on and monitoring the progress of agricultural investment projects and activities.
- Improving the mapping and management of land use to enhance rational use of agricultural land and stop deterioration of the environment.
- Control of national pests in collaboration with concerned international organizations.
- Development of innovative modern agricultural technologies for sustainable agricultural development activities.
- Encouragement of strategic partnerships with foreign governments and private sector to facilitate the exporting of agricultural products from Sudan.
- Approving and allocating agricultural investment projects for foreign direct investment.
- Developing and commercializing traditional agriculture to enhance rural development and poverty alleviation.
- Improving agricultural extension services and programs.
- Intensifying international and regional cooperation in the area of agriculture development and conservation.

The Ministry of Oil, Gas and Minerals (MOGM) is the principal government entity responsible for planning and policy formulation related to energy supply and demand, investments in petroleum and other minerals and

similar activities in Sudan. The Ministry has among its administration a specialized department for biofuel production and distribution.

Entry points for MOGM for enhanced cooperation and alignment of sector and national strategies include, among others:

- Formulating plans and policies related to oil and gas and biofuel and supervising implementation.
- Supervising the transportation, distribution and sales of petroleum and by-products.
- Developing and upgrading staff skills and knowledge related to oil and gas.
- Promoting research in oil and gas development, distribution and logistics.
- Identifying and assessing sources of biofuel production including oilseeds, sugarcane, crop residues, livestock residues, garbage, etc.
- Organizing and enacting laws that encourage investment in biofuel.
- Developing standards and guidelines to promote the use of biofuel with petroleum and the distribution of liquid biofuel.

3.2 Cross-Sector WEF Institutions

The main cross-sector institutions in Sudan are described below.

The Food Security and Nutrition Council (FSC) is chaired by the Vice President and supported by a Food Security and Nutrition General Secretary. The Council has members representing the Ministry of Agriculture and Forests, Ministry of Health, Ministry of Livestock Resources and Fisheries, Ministry of Water Resources, Electricity and Irrigation, the Humanitarian Aid Commission and the Strategic Reserve Authority. The mandates of the Secretariat are to prepare a comprehensive national food security and nutrition policy, as well as a national work plan with specific programs and projects related to food security and nutrition, and to provide support in cases of emergency or crisis.

The Higher Council for Environment and Natural Resources is a coordinating body including all line ministers and relevant national institutions as members. The Council is responsible for developing policies on natural resources conservation, development and protection in coordination with competent authorities. It also coordinates national efforts to join Global Conventions, Agreements and protocols pertinent to climate change and the environment.

The HCENR Act (1991) stipulates its functions in:

- Laying down general policies and long-term plans for environmental protection and sustainable development of natural resources,
- Coordinating efforts directed towards environmental and natural resources management among concerned governmental agencies and between federal and state governments,
- Periodically reviewing relevant legislation and recommendations to make them more effective instruments for sustainable development,
- Encouraging and supporting research on the environment and natural resources,
- Promoting environmental awareness and education.

Research Centers are discipline-oriented research institutions that support the WEF Nexus by carrying out a number of research activities at the federal and state levels. These institutions include:

- Land and Water Research Centre
- Water Harvesting Research Institute
- Hydraulic Research Station
- National Corporation for Rural Water
- Soil and Water Studies Centre
- Agricultural Research Corporation Centers
- National Centre for Research
- Desertification and Water Research Centre

Universities and Higher Learning Institutions: More than 100 universities and colleges are distributed throughout the country. Some are specifically engaged in water resources management, natural resources management and fisheries-related disciplines.

The State Ministries and associated locality government offices are responsible for planning and implementing WEF between states, inside states and within the localities of each state.

State-level institutions are weak in dealing with WEF interstate resources and do not possess authority or capacity to manage commonly shared streams and groundwater aquifers.

3.3 Parallel Institutions

Sudan established WEF parallel institutions that overlap with the basic mandates of the concerned ministries. Two examples are the establishment of the Water Resources Council and the Agricultural Revival Corporation.

The Ministry of Water Resources, Electricity and Irrigation established the National Water Resources Council (NWRC) to advise the Ministry on WEF. The members of the council included the Ministry of Agriculture and Forests, the public irrigation schemes managing boards, the State Ministries of Agriculture, Animal Resources and Irrigation (SMAARI), the Hydraulic Research Station, the Agricultural Research Corporation (ARC) besides other affiliated research units (livestock, forestry, fisheries) and the University of Gezira. The Council is currently not operating.

The NWRC is composed of senior government decision makers who are fully consumed with their own specific mandates due to their seniority and are thus not always free to attend lengthy Council meetings. Moreover, the institutional and financial capacity of the supporting staff and logistics are weak and are not commensurate with the expected objectives of the Council.

The Agricultural Revival Corporation was established to implement the Green Mobilization Program of 2008 (GMP). The Agricultural Revival Program (ARP) Executive Program was executed by an independent entity separated from the Ministry of Agriculture, which resulted in overlapping agendas. The ARP currently faces financial problems.

The Agriculture Season Committees

The Nexus approach is to increase food-production efficiency and minimize the costs of irrigation and energy supplies. The case of inefficiency in the use of resources is reflected by the fact that there are too many committees involving the most senior entities at the cabinet level. An example is that of the agriculture season committees given below:

- The Higher Committee for the Agriculture Season under the Cabinet presidency,
- The Follow-up Committee of Agricultural Inputs under the president of the Economic Committee,
- The Ministerial Committee for the Agricultural Season under the Minister of Agriculture, which sets the plan in co-ordination with all states and schemes that is then raised to the senior committees for approval,
- The committee for supplying the financial, input and fuel requirements of the agricultural season,
- Follow-up States committees,
- The Ministry of Agriculture Follow-up Mechanism, which has specialized arrangements for the allocation and distribution of fuel, inputs, and credit,
- The Irrigation and the Rainfed Units in the Ministry of Agriculture are responsible for coordination and follow up and monitoring the progress of the flow of the finance, agricultural inputs and fuel.
- The Units have two standing representatives in the Ministry of Oil, Gas and Minerals who follow up the flow of fuel to the different states. They have direct contact with state representatives for feedback on the situation of the fuel flow into the respective states.

The administration and management in WEF Nexus sectors of Sudan is highly complex. They have overlapping mandates and responsibilities and non-defined limits of authority. Conflicts between federal and state ministries in implementing WEF programs and projects at state and local levels are common. Communities targeted with interventions seldom participate in policy formulation processes. Weak budgets constrain a number of pipeline programs and projects for local communities.

A summary of the assessment of the performance of key WEF Sector institutions are shown in the following Table 3.

Table 3: Assessment of the performance of key WEF Sector institutions

Institution	Function under-performing	Causes of under-performance
Ministry of Water Resources, Irrigation and Electricity (MWRIE)	Poor coordination between institutions involved in agricultural water management	<ul style="list-style-type: none"> Limited technical and financial resources Inter-ministerial competition Conflicts between institutions Tedious and prolonged policy-reform process
	Poor water resources management and development in the States and at national level	<ul style="list-style-type: none"> Lack of development of human skills Lack of coordination between Central (national) and States Inadequate provision of finance to support investment in water resources and management
National Council for Water Resources (NCWR)	Setting policies	<ul style="list-style-type: none"> Limited technical resources Inter-ministerial competition Conflicts between institutions Slow and difficult to meet in one place and one time
Ministry of Agriculture and Forestry (MA&F)	Inadequate rural advisory services and technology transfer	<ul style="list-style-type: none"> Limited technical and financial capacity Limited human resources Overlapping of National and State administration
	Poor planning of agricultural resources in Sudan	<ul style="list-style-type: none"> Limited involvement of private sector in agricultural water management development Rules and regulations in AWM investments are not enforced
Ministry of Oil, Gas and Minerals	<ul style="list-style-type: none"> Management of petroleum refineries Management of imported diesel fuel distribution among users 	<ul style="list-style-type: none"> Lack of technical and financial capacity Lack of skilled human capacity Absence of coordination with relevant Ministries and institutions

Source: AgW-FAO (2015).

4 WEF STRATEGIES, PLANS, POLICIES AND LAWS

4.1 Sudan WEF-Related Strategies

The 25-Year Development Strategy (2007-2031) is the current development strategy providing the vision and strategic objectives for the economy. The Strategy is translated into successive Five-Year Development Plans subject to annual and periodical revision and reform. The Strategy and associated development plans are aligned with the MDGs 2000-2015 and the SDGs 2015-2030. In 2018 the Strategy was updated to indicate that agriculture (including both crop and animal production) and water resources and the energy sectors are considered critical national engines for development. In order to augment the water, energy and agricultural sectors' roles, it will be necessary to implement a comprehensive Nexus strategy that takes into account the links and coordination among their related activities.

The main goal of the strategy is to realize a 7%-increase in the gross national product and an increase in the contribution of private-sector investment by more than 65%. In both areas, limited achievements have been made up to now. In the area of the WEF Nexus, key strategic and policy objectives include:

- Develop water resources and irrigation facilities:
 - Develop available water resources; increase water reservoirs and rivers and ravines storage capacity; exploit artesian water fisheries; expand water catchment methods and provide drinking water for societies and livestock;
 - Rehabilitate irrigation services to upgrade the efficiency of water usage; introduce appropriate technologies to optimize usage and disseminate water awareness;
 - Protect dams and irrigation canals against silting and water hyacinth, and regulate water use to prevent quantitative and qualitative deterioration.
- Develop the energy sector:
 - Provide the country with a sustainable supply of electricity by expanding generation and distribution capacities, and dealing with the grid losses,
 - Enhance administrative and commercial aspects opening the markets for electricity utilities, generation, distribution and sales to private investment,
 - Increase electricity generation capacity to meet nationwide production and consumption requirements,
 - Expand the national electricity network; rehabilitate the hydroelectric generating stations and strengthen their operational capacity,
 - Improve economic cooperation among the Eastern Nile Basin countries (Egypt, Sudan and Ethiopia) as part of the electrical connection project,
 - Generate electrical energy through renewable energy resources such as solar energy, wind, hydropower and artesian heat,
 - Extend petroleum distribution networks to meet the requirement of production and consumption sectors all over the country.
- Increase food and cash crop area and production:
 - **Double the irrigated cultivated area by gravity, spate irrigation and groundwater extraction to reach 10 million feddans.**

- **Double rainfed cultivated area to reach 50 million feddans.**⁴
- Increase competitiveness through vertical integration,
- Expand water harvesting programs in rainfed areas,
- Promote public-private sector cooperation in agriculture,
- Increase the number of electric pumps in irrigation schemes to reduce overall costs,
- Improve fishery resources to meet domestic and international market demand.

The development goal of Sudan in the context of the UN Sustainable Development Goals (SDGs) is that Sudan will realize these Goals together with the commitment to the 2015 Paris Agreement on climate change.

The Sudan 25-Year Development Strategy for 2007-2031 is very ambitious and forms the backdrop for all government-issued strategies and plans. The strategy encompasses three dimensions: economic, social and environmental. Each WEF sector dimension is well defined with specified challenges and policies and economic indicators.

4.2 WEF-related Policies

The Ministry of Water Resources, Electricity and Irrigation (MWREI) issued the following policies:

- **Water Resources Policy (2000)** aims to strike a balance between satisfying irrigation supply needs and hydropower generation to meet the demand of housing and industry for energy; it also aims to develop and increase water supply and distribution in rainfed areas.
- **Sudan Policy and Strategy on Integrated Water Resources Management (2007-2022)** recognized water as a scarce, vulnerable resource and identified the need to distribute equitable water supplies to different states and users within the country. Its ongoing objective is to create awareness about expected future water scarcity and about the importance of treating water as an economic good.
- **The National Plan for Development and Utilization of Water Resources (2014)** aimed to enhance rainfall and surface water utilization and management. It was able to increase water supplies in rural areas **but lacked coordination with other line ministries at the federal and state levels.**

The Ministry of Agriculture and Forests formulated the Agricultural Revival Program (ARP), which proposed policies that link WEF to agriculture through:

- Generation of more hydropower and solar energy as an alternative to use of diesel pumps in agriculture.
- Scale up of water harvesting projects for small producers under the traditional rainfall system.
- Rehabilitation of forests, rangelands, and pastures to reduce the effects of severe deforestation and overgrazing.
- Reform the private-sector mechanized farming system using appropriate technology to optimize the use of diesel energy for land preparation and harvesting purposes.

⁴ One feddans equals 0.42 hectares.

A summary of the performance of government institutions with respect to policy objectives and an assessment of the reasons for failing to achieve certain objectives is provided in Table 4.

Table 4: Assessment of the performance of key WEF sector policies

Policy	Unachieved objectives	Reasons for non-achievement
Sudan Policy and Strategy on Integrated Water Resources Management TF: 2007-2022	<ul style="list-style-type: none"> Establishment of a financing mechanism for funding of water resources management functions Promote participation and engagement of the private sector and other stakeholders in service delivery 	<ul style="list-style-type: none"> Multi-users of water resources and overlapping responsibilities Lack of economic incentive Limited private-sector investment in water sector Decreased efficiency and competitiveness of the sector
	Enhance creation of additional rain- and surface-water reservoirs	<ul style="list-style-type: none"> The responsible Dam Unit for water harvesting and hafirs lacks financial capacity Poor coordination between Dam Unit and relevant institutions The policy does not address modern technologies in irrigation
	Improve use and management of existing and planned water-resources storage	<ul style="list-style-type: none"> Existence of irrigated schemes with poor management and financial capacity Conflicts of interest among stakeholders Weak coordination deprives vested interests of certain parties in management boards
	Evaluate and enhance transfer of improved water-users associations system to other irrigation schemes	<ul style="list-style-type: none"> Deterioration of irrigation infrastructures at scheme level Financial requirement for maintenance is beyond financial capacity of the farmers Slow performance of institutions
	Generate incentives to promote private-sector investment in manufacturing of water pumps, drilling equipment, water pipes and tanks and supplies of spare parts	<ul style="list-style-type: none"> Lack of government commitment; promotes industry of irrigation water equipment which encourage use of technologies that enhance the efficiency of irrigation water Relative resistance to risk of competition of imported equipment and machinery
The National Plan for Development and Utilization of Water Resources (2014)	Aimed to enhance rainfall and surface-water utilization and management	<ul style="list-style-type: none"> It was able to increase water supplies in rural areas but lacked coordination with other line ministries at federal and state levels
Ministry of Agriculture and Irrigation Plan – Irrigation Sector 2015 – 2019	Maintenance of basic irrigation infrastructure; introduction of appropriate technology and control methods for meeting increased demand for irrigation water and reduction of water losses	<ul style="list-style-type: none"> Lack of government commitment to provide financial resources
Encourage exploration of petroleum resources Import diesel fuel Provide agriculture with diesel fuel supply as top priority Removal of price subsidy	<ul style="list-style-type: none"> The country lost 70% of oil production capacity due to the separation of South Sudan Oil drilling polluting soil, water and vegetation Widespread leakage of treated water into forest, pastures and water reservoirs Release of oil vapor into environment Irregular supply and insufficient storage of petroleum energy for agriculture 	<ul style="list-style-type: none"> New concession in areas of Sudan; Ministry of Oil and Gas estimates Sudan reserve to be round 514,300 billion barrels Allocate adequate foreign currency for importing low-cost diesel fuel Introduce efficient energy consumption technology Expand fuel-storage facilities before onset of rainfall and address petroleum-fueled air pollution

Source: AgWA-FAO (2015), pp. 58.

4.3 WEF Related Laws

The main laws related to water resources administration and management and their assessment in Sudan are described in the Table 5.

Table 5: Laws on water resources management and their assessment in Sudan

Specific targets not achieved	Aspects and resistance to change
Irrigation and Drainage Act (1990): Aims to regulate the use of irrigation water and drainage facilities; permits construction of feeder roads inside irrigation schemes	
Regulate use of irrigation water and drainage facilities	Water use sources are not defined. The Act does not target the vulnerable and poor people. There is resistance to change as the Act is relatively old
Water Resources Act (1995): Established by the National Council of Water Resources (NCWR) with broad functions and authorities to regulate and monitor the utilization of water resources from different sources (Nile, non-Nile, water courses and ground water) for various reasons (irrigation, drinking water, industry, hydro power and sanitation)	
Improve efficiency and effectiveness of water management - improved coordination between actors in the water sector	Non-operating national council for water as well as lack of coordination and overlapping of responsibilities between different actors
Gezira Scheme Law of 2005: Aims at increasing the involvement of tenants in the management of irrigation water at field level, increasing crop productivity and improving socio-economic welfare	
Promote decentralization, privatization and more farmer participation in the management of the Scheme; enhance field water management and utilization	Farmers unable to effectively engage senior-level management of large scheme administrations; water users' associations lack technical capacity; resistance to change due to weak enforcement of the Act to formulate regulations that organize the relation between water users' associations and beneficiaries
The Environment (Protection) Act, 2001: Creates an enabling environment for institutional capacity and formulates policies protecting natural resources, including water resources	
Create an enabling environment for institutional capacity	The established Higher Council for Environment and Natural Resources lacks the administrative power to enforce functions and mandates; no enforcement of protection laws and penalties
Local government law of 1998 is concerned with establishment of locality councils that issue water legislation related to non-trans-boundary waters under its geographical authority	
Regulate trans-state water resources	Locality councils were not established or not functional; resistance from federal government to state development of inter-state water resources

Source: Ministry of Water Resources, Electricity and Irrigation and AgWA-FAO (2015)

4.4 Sudan Nationally Determined Contributions (NDCS)

The National Adaptation Plan (NAP, 2014) illustrates that the frequency of extreme climatic shocks is increasing, particularly droughts and floods. Frequent droughts threatens about 19 million hectares of rainfed mechanized and traditional farms, as well as the livelihoods of many pastoral and nomadic groups; more than 70% of the population in Sudan depends on this sector for their livelihood. Floods in Sudan can either be localized, caused by exceptionally heavy rainfall, or more widespread, caused by the overflow of the River Nile and its tributaries (NAPA, 2007). Non-climatic factors that contribute to the vulnerability of communities in different parts of Sudan include unsustainable management of natural resources and socioeconomic factors such as poverty, lack of income diversity, unequal distribution of income, urbanization, population growth, lack of adequate infrastructure and lack of international support and investments. Table 6 shows the commitment of the Government of Sudan with respect to the WEF Nexus.

Table 6: Energy programs of action and their objectives

Program of Action	Description	Objectives of Actions
Integration of renewable energy in the power system	<p>Objective: Integration of renewable energy in the power system of Sudan, target of 20% by 2030</p> <ol style="list-style-type: none"> 1) Wind energy: 1000 MW (grid connected) will be applicable in strong wind regime areas. 2) Solar PV energy: 1000 MW (on and off grid) will be applicable in different states within Sudan. 3) Solar CSP technology: 100 MW (grid connected) will be applicable, especially in the northern part of Sudan. 4) Waste to Energy: 80 MW (grid connected) will be applicable in several intended sites. 5) Biomass Potential: 80 MW (grid connected); e.g., the sugar industry. 6) Geothermal Potential: 300 MW in different states of Sudan. 7) Small Hydro Plants: 50 MW (grid connected) especially in combination with irrigation sites and small hydro plant projects. 8) Solar rural electrification through installation of 1.1 million Solar Home Systems (SHSs) by 2030 	<ol style="list-style-type: none"> 1) Harness the potential of Sudan's renewable energy resources to make electric energy available nationwide 2) Achieve a competitive price of energy from renewable sources, which will lead to fuel saving 3) Diversify energy supply sources to ensure energy security and protect the environment 4) Be a part of global energy development, which is expected to lower prices in the future 5) Support the national economy by technology and knowledge transfer, capacity building and promoting the local renewable energy industry 6) Contribute to the development of the different regions of Sudan 7) Provide access to electric energy supply to rural areas far from the national or isolated grids (and for which grid extension is not a feasible solution)
Energy efficiency	<p>GHG mitigation is achieved through efficient energy usage, including:</p> <ol style="list-style-type: none"> 1) Reduction of loss in transmission and distribution networks 2) Rehabilitation of the cooling systems in hydroelectric stations 3) Increasing readiness of the power station – matrix turbines. 4) Reduction of the costs of producing electricity and auxiliary consumption from thermal power plants 5) Improvement of specific fuel consumption in thermal power plants 6) Replacement of incandescent lamps with CFL and LED lamps in residential sector 7) Establishment of the labelling system for electrical appliances 	<p>The greenhouse gas emission reductions associated with energy efficiency are calculated at approximately 6,500 GWh during 2016-2030.</p>
Electricity thermal generation using Natural Gas	<p>Production of 2,300 MW using natural gas in different parts of the country</p>	<p>GHG emissions reduction, fuel cost reduction and enhancement of social and economic development in the country</p>

Source: Ministry of Water Resources, Electricity and Irrigation SEDC (2017)

Nexus coordination is hindered by sector-oriented formulation and design. This has also contributed to overlapping and sometimes conflicting laws and policies. The practice of establishing high-level committees of senior administrators to coordinate and add synergy to plans, policies and laws is not effective since it builds on a sector-by-sector planning approach. The relevant inter-linkages are not considered at the technical stage when plans and policies are being designed. Each sector addresses the issues in the context of its own perspectives and benefits. In essence, current plans are designed almost for crisis mode, rather than for integrated, sustainable development.

5 CROSS-BOUNDARY NEXUS ISSUES

Sudan shares common surface and underground water resources with neighboring countries. These include the sharing of surface rivers along the eastern front with Egypt, Eritrea and Ethiopia as well as sharing of the groundwater resources on the northwestern front with Egypt, Libya and Chad. Sudan has signed agreements with Egypt and Ethiopia on the GERD, is a member of the Nile Basin Initiative, but in a holding pattern, and has preliminary agreements in place with Chad, Libya and Egypt on the Nubian Sandstone Aquifer.

Water Agreements

While trans-boundary cooperation exists, the lack of a consistent legal framework is a major drawback. Trans-boundary issues are mainly covered by consultation in working groups to avoid submission of contradicting national reports. The present cross-country WEF Nexus cooperation among Sudan, Egypt and Ethiopia on the River Blue Nile has been crystallized through exhaustive rounds of negotiations and debate. The three countries signed the Declaration of Principles (DOP) on the Great Ethiopian Renaissance Dam (GERD) in 2015 to signal closer cooperation, forming a solid base for sharing the costs and benefits that may accrue from the dam. The Declaration also aims to enhance legal standards for institutional cooperation and even integration through win-win joint projects. The guiding principles of the initiative are Cooperation, Development, Regional Integration and Sustainability; Equitable and Reasonable Utilization; Cooperation in the first filling and operation of the Dam; Confidence Building; Exchange of Information and Data; Dam Safety; Sovereignty and Territorial Integrity; and Peaceful Settlement of Disputes.

The steps towards reaching economic cooperation among the Nile Basin Initiative (NBI) countries, however, were not progressive. That initiative was signed in February 1999 by nine countries (before the split of Sudan into the Republic of Sudan and the South Sudan in 2011). The NBI was a transitional institution replaced by the Cooperative Framework Agreement (CFA) in 2010 endorsed by six countries, namely Ethiopia, Kenya, Uganda, Rwanda, the United Republic of Tanzania and Burundi in 2011. Egypt and Sudan opposed the CFA agreement as it gives deciding power over large-scale hydraulic projects to a commission representing all the signatories. The CFA was put on hold due to the Egyptian and Sudanese stand.

Sudan shares other water resources, including the Gash and Baraka streams with Ethiopia and Eritrea, Azum and Hawar with Chad, and shares seven transboundary aquifers with neighboring countries (including the Nubian Sandstone Aquifer system, Lake Kundi and Lake Keilak). These water resources are not covered by any legal or institutional setup.

Cooperation allows for:

- Better management of floods, droughts and groundwater and better protection of watersheds and wetlands.
- Promotion of regional networking, monitoring, and implementation mechanisms among countries sharing common aquifers. Management of the Nubian Sandstone Aquifer must be governed by legal agreements to regulate the pumping of such resources. Sudan lacks the capacity to monitor regular groundwater withdrawal by Libya and Egypt from the aquifer on its own.
- The GERD agreement allows countries to share the benefits of regular water supply, multipurpose storage – including for irrigation, hydropower generation, navigation, flood and drought mitigation – and environmentally sustainable management.

Cross-boundary cooperation among countries is recommended for managing water resources. The cooperation between Sudan, Egypt and Ethiopia on the River Blue Nile front has always been solid and recently has been strengthened by the construction of the GERD. Upon the completion of the GERD, mutual benefits will evolve which ultimately will encourage the three partners to be ready to enter into joint venture projects. Cross-country collaboration needs to recognize differential socioeconomic development and national goals for poverty alleviation.

Strengthening the communication and outreach of WEF Nexus requires the consideration of political relationships within and among countries. Recognizing socioeconomic-development goals and poverty-alleviation interests is an entry point for maintaining synergy and close linkages inside and among countries implementing the WEF Nexus approach. Emphasizing the importance of creating strong linkages between poverty alleviation and achievement of food-security objectives will provide a major driving force for improving livelihoods and environmental sustainability of natural resources. This has to be done within a mechanism that creates close inter-linkages for activating the green economy and controlling land degradation, reducing vulnerability to climate change. Therefore, it is important to develop the communication capacities of WEF-sector staff and to recognize and support the role of media in raising awareness about such shared needs and benefits.

6 OVERALL ASSESSMENT AND RECOMMENDATIONS

6.1 The Challenges of the WEF Sectors

Geopolitical challenges

The main challenges facing water, energy and food security in Sudan are related to inadequate institutional setup and governance. Another important challenge is the dependence of Sudan on water resources originating outside the country and on variable rainfall. Likewise, prolonged civil conflicts, recurrent droughts and poverty and associated rural-urban migration, have created new economic challenges while exacerbating existing ones. These present a serious obstacle to policy makers and planners seeking to manage WEF-related resources for sustainable development. All of these present serious obstacles to policy makers and planners seeking to manage WEF and related resources for sustainable development.

WEF-sector challenges

The most pressing problem facing Sudan now is the need to meet the growing demand for water, energy and food while contending with the expected impact of climate change and climate variability, which is already manifesting itself in many parts of the country. The recurrent droughts and floods and shifts in rainfall patterns inevitably affect food, water and energy production and consumption. The implementation of climate change adaptation projects and the development of resilience programs have garnered huge support from international organizations, mainly the UNDP, African Development Bank (AfDB) and the Global Environment Facility (GEF) in marginal lands.

While Sudan's water policy and strategy are based on the WEF Nexus concept, implementation is still preliminary and the country's water-sector management challenges are far-reaching and complex. For instance, Sudan must address the aging and fragmentation of water-management institutions, while facing the challenge of providing adequate supplies of fossil and renewable energy, while also saving on the heavy consumption of biomass energy. The importing of diesel fuel to meet the demand for thermal energy generation, food production and food transportation is constrained by the tradeoff of allocating scarce foreign currency to the purchase of other essential imports, including wheat, drugs and medicines – posing a challenge to the efficient, cost-effective use and management of fossil-fuel resources. Moreover, the elimination of fuel subsidies in 2013 and the irregular supply of diesel fuel has increased the cost of crop production and contributed significantly to delays in land preparation and crop harvesting across the country.

Pursuing food security without due consideration of land use and watershed planning has resulted in widespread land degradation and low crop productivity and production. The mismanagement of irrigation and rainfall water resources, the severe deforestation and overgrazing of rangelands and pastures, and the conflict between farmers and pastoralists are all outcomes of fragmented WEF planning and implementation programs and policies. Poverty looms over 50% of the population and is even higher in rural areas. About 13 million people are food insecure and 30% of the population, especially in the Red Sea State, suffer from chronic hunger. Undernutrition is high and particularly widespread among children and mothers.

Achieving the security of one of the WEF sectors at the expense of the other two, without considering the comparative economic advantage and the environmental repercussions on society in general and on local communities in particular, would endanger the sustainable development of livelihoods and the performance of the national economy as a whole.

Economic challenges

Macroeconomic instability has a large impact on WEF-related programs. The scarcity of foreign currency limits the imports of capital goods and intermediate material and inputs—including spare parts and diesel fuel—which has significantly affected investments and operations in WEF sectors. The high costs of imported fuel and water,

energy and agricultural equipment maintenance reduce the competitiveness of Sudan's food crops in the domestic and foreign markets. Furthermore, Sudan does not adopt or promote economic tools that enhance water use efficiency (WUE).

In summary, the poor WEF-sector value chains, low crop productivity and weak competitive capacity are consequences of economic mismanagement of the WEF resources. A myopic pursuit of the benefits that come with financing one sector or activity without consideration for the opportunity cost of ignoring the other sectors leads to awkward allocation of economic resources. These WEF planning and implementation approaches inevitably necessitated tradeoffs for policymakers (i.e., between allocating financial resources to large or small water dams, or between expanding crop land or conserving land for livestock grazing). The ultimate results are recurring conflicts between crop producers and pastoralists over land and water.

Research, technology and Innovation challenges

The successive strategic plans and policies have always ranked WEF research development and technology transfer as low priorities. Water, energy and food scarcity and competition have motivated the development of technological solutions. The introduction of appropriate technologies including renewable energy, zero tillage and conservative agriculture and modern irrigation tools (i.e., bubble, drip and sprinkler irrigation) are driving forces that integrate optimum management of the Nexus' three components with technology. Indeed, technological and innovative solutions within the WEF Nexus, where two, or all three, components of the Nexus are integrated as inputs would enhance resource efficiency and expand the available natural resource base, thus bolstering the sustainability and security of the three resources. Under the current constraining conditions in Sudan, such technological and innovative solutions may prove critical to the adoption of the WEF Nexus approach by various stakeholders.

Institutional challenges

Key facets of institutional challenges are summarized in the following:

i. Improving institutional coordination and building WEF-sector networks

- There is unanimous consensus among senior decision makers that existing senior inter-ministerial councils and committees play a minimal role in integrating WEF-sector-based programs and policies.
- The actual process of planning and policy design is undertaken by the technical staff in the different WEF sectors based on general guidelines issued by the senior councils and committees.
- The preparation of plans and policies at the sector-minister level generally lacks coordination and synergy.

ii. Duplicated and/or overlapping organizational structures and mandates of the WEF sectors at the federal and state levels

- Resolving the lack of coordination and consultation among federal, state and community partners, especially women, is critical to formulating and implementing viable WEF policies, strategies and plans.
- Thus, the absence of an institutional platform for the integrated formulation and management of WEF Nexus policies and plans resulted in sector-based and fragmented plans, policies and implementation of WEF activities in Sudan.

iii. Tardy establishment of trans-boundary cooperation and legal framework for managing shared groundwater resources

- Sudan is late in establishing trans-boundary cooperation and a legal framework for assessing, planning and managing shared groundwater aquifers with Chad, Libya and Egypt.
- Libya and Egypt have already started tapping the shared groundwater resources.

- The establishment of basin/aquifer authorities remain in early stages and trans-boundary issues are mainly covered by consultation in working groups to avoid submission of contradicting national reports.
- iv. Poor institutional capacity of WEF sectors for planning, policy formulation and monitoring activities**
- Despite policies being embedded in several plans (the 25-Year Development Strategy (2007-2031), NAP, NAPA, NBSAP, Five-Year Development Reform Programs); and despite responsibilities being divided (formulation of WEF policies by federal ministries and implementation by states and locality governments) WEF activities are not effective, economic tools that enhance water use efficiency are not promoted and the benefits of financing dams were not compared to the benefits foregone by clearing trees including acacia trees producing gum Arabic (used in building the dams). The ultimate result are recurring conflicts between crop producers and pastoralists over land and water.
- v. Limited use of knowledge, database building and information technology management**
- The existing level of data quality and data sharing both in country and at trans-boundary levels does not support the formulation of quality policies and plans and will not guide proper decision making on WEF-related issues.
 - There is little data on groundwater resources and aquifers, on energy-sector supply and demand in the rural areas or on food-production capacity (especially among small households under rainfed production systems).

The WEF challenges are embedded in the poor coordination and lack of synergy among WEF sectors – both among federal line ministries and among the federal and state ministries and local communities. The weak institutional capacity for planning and policy formulation and inadequate data quality and availability do not support short- and long-term planning.

Human needs, SDG challenges

The provision of basic human needs, mainly food and water, is a crucial component of poverty alleviation plans in Sudan. It is closely aligned with the MDGs and SDGs of the United Nations and its respective institutions. The SDGs laid down specific security targets for the three WEF sectors. These are SDG2 on food security, SDG6 on water and sanitation and SDG7 on energy. These goals have to be approached as a package to internalize the WEF-Nexus integrated approach.

Trans-boundary challenges

With more than 60% of surface water resources originating outside Sudan, realizing benefits from shared water basins remains a major challenge. The high priority given to trans-boundary cooperation with Ethiopia and Egypt on the River Blue Nile is contested by the need for economic trans-boundary cooperation with Libya, Egypt and Chad on the Nubian Sandstone aquifer.

Despite the existence of several basin-management arrangements, the limited scale of planning for the sustainable management of the Nubian Sandstone Aquifer prevents Sudan from benefiting proportionately to its share in this important groundwater resource. Data sharing is limited at trans-boundary levels and data reliability is questionable. The challenge is to undertake the preparatory measures required for equipping the negotiating staff with adequate data on the volume and depth of these shared groundwater resources. Such an undertaking requires knowledge and understanding of international cooperation laws and diplomacy, so as to ensure the preservation of the rights of Sudan to this common water resource.

Communication and outreach challenges

There are hardly any communication and outreach activities between WEF Nexus staff and local communities. The poor communication capacity of WEF-sector staff and the weak presence of media has kept awareness of communities low. Changing the political and socioeconomic perspectives and opinions of staff and local communities is restricted in scale and coverage. There are no linkages between WEF-sector activities and related poverty alleviation strategies, food-security objectives, livelihoods and environmental sustainability in the different parts of the country.

6.2 Recommendations

6.2.1 Opportunities for improving the WEF Nexus

Together, water, energy and food form a complex and intertwined Nexus; each component affects the others. The increasing demand for the three commodities will affect supply-chain security across all sectors. By developing integrated WEF Nexus policies and solutions, these challenges can be converted into opportunities. Minimizing losses in the production, supply, and utilization of water, energy and food in Sudan can contribute significantly to bridging the demand gap, save substantial amounts of resources used in their production, reduce environmental degradation, and achieve the targets of the SDGs and Paris Climate Summit.

Decision makers have to be aware of the following: The economic valuation of the contribution of each of the three sectors has to be weighed within the WEF Nexus framework. Improving efficiency and productivity is more cost-effective than increasing supply capacity. Improving irrigation efficiency and reducing post-harvest losses would result in saving of water and energy resources used in the production and distribution of agricultural and food commodities. Achieving development sustainability depends on the provision of regular adequate resource inputs along the different stages of the supply chain.

Energy is a critical input in the production of food and water along different stages of the WEF Nexus supply chain. Any negative impacts of the high dependence on unsustainable energy sources (i.e., volatile prices) will spill over to the environment. Renewable energy technologies present clean energy in a manner that reduces tradeoffs and strengthens synergies between sectors, thus improving overall water, energy and food security. Moreover, clean energy and resilient ecosystems represent natural solutions that are compatible with the broader green economy objectives laid out in the SDGs and the 2015 Paris Climate Summit. The Nexus approach supports the transition of the existing system into a sustainable one, negotiating for fair tradeoffs and generating additional benefits that balance with the transaction costs associated with the immediate integration of the WEF sectors and cross sectors.

The WEF Nexus enables systematic thinking and organizational building among the three sectors. To achieve water, energy and food Nexus-security goals, there is a need for the development of a coordinated, harmonized Nexus knowledge base and sustainability indicators and metrics beyond GDP that cover all relevant spatial and temporal scales and planning horizons. The resource limitations in each of the three sectors necessitate a shift towards a low-carbon economy, resource use efficiency, demand management and more sustainable consumption patterns. Finally, there is an urgent need for de-coupling energy use and economic growth by transitioning to a “resource-efficient” economy where societies value water, energy and food resources, participate in the decision-making processes, and manage natural resources wisely and efficiently.

6.2.2 Integrating WEF Nexus within existing institutions

The proposed recommendations capitalize upon the existing WEF committees to provide an enabling platform for integrating the WEF sector and cross-sector resources into a solid network framework.

Reorganizing Existing Institutional Structure

- Capitalize upon the existing WEF committees to provide an enabling platform for integrating the WEF sector and cross-sector resources into a solid network framework. This requires building the institutional capacity of the staff of the different WEF-sector ministries and authorities, supporting them with proper database and databank development and an efficient information management system.
- Move from a situation where certain ministries dominate decision-making while reorganizing existing institutions and mechanisms for enhanced synergy among the three sectors.

The administration and management of water, energy and food is sector-based and led by the three main ministries related to the WEF. Sometimes certain line ministries dominate the decision-making process, steering attention towards the development of their respective interests. However, this does not conform to the objectives of the integrated WEF Nexus approach. There is thus a need to reorganize and strengthen **existing institutions** and **mechanisms** for integration and development of synergies for sustainable development.

Mainstreaming WEF Nexus within the existing institutional structures must include:

- Increasing policy coherence by ensuring that synergies and tradeoffs among water, food and energy are identified in the design and implementation of policies, plans and investments.
- Abandoning siloed thinking and vested interests.
- Creating awareness about the concept of WEF Nexus at higher policy-making levels and at lower technical staff levels.
- Specifying clear mandates and responsibilities of technical committees.

6.2.3 Institutional Capacity Building Requirements for Mainstreaming the WEF Nexus in Sudan

Strengthening the institutional capacities of WEF-sector ministries, agencies and stakeholders for planning and policy formulation and project implementation and monitoring is highly recommended (personal communication, Dr. Korena, Dr. Egaimi and Prof. Seifeldeen⁵). Capacity building is crucial to solid planning and policy formulation and to ensure the integration and mainstreaming of the WEF Nexus approach into existing national strategies, policies and programs. The comprehensive monitoring and evaluation (M&E) systems for follow-up and evaluation of WEF Nexus activities and performance are required to enhance the continued reform and adjustment of the WEF activities towards achieving their targeted objectives. The existing M&E activities, which focus on the River Nile system and tributaries, have to expand to accommodate the other water resources in the country. The seasonal streams, groundwater and rainfall resources need monitoring and reassessment so

⁵ Section 9 includes a list of people interviewed for the study.

that further reform and improvements can be made. The upgrading of weather monitoring stations to international standards is also a prerequisite as recommended by the Ministry of Water Resources, Electricity and Irrigation.

Institutional Capacity Development

- Strengthening institutional capacities of WEF-sector ministries, agencies and stakeholders for planning and policy formulation and project implementation
- This is crucial to solid planning and policy formulation and to ensuring the integration and mainstreaming of the WEF Nexus approach into existing national strategies, policies and programs.
- Implementing M&E systems for follow-up and evaluation of WEF Nexus activities and performance to enhance the continued reform and adjustment of the WEF activities towards achieving their targeted objectives.

Monitoring and Evaluation shall identify relevant indicators for assessing the performance of WEF-sector programs and activities. Table 7 shows an example of SDG targets and indicators related to WEF Nexus.

Table 7: SDG targets and related WEF-sector indicators

WEF-sector-related SDG targets	WEF-Nexus-related SDG indicators
Increasing Resource use efficiency	<ul style="list-style-type: none"> ○ Water supply and demand and water loss ○ Energy supply and demand by source and energy gap ○ Food production and consumption and food gap ○ Allocation of land use among WEF sectors ○ Food insecurity level ○ Malnutrition level
Improving human security	<ul style="list-style-type: none"> ○ Percentage of people with access to safe drinking water services ○ Percentage of people with access to energy sources (electricity, biomass, fuel) ○ Percentage share of water allocation and use by WEF sectors related to ecosystems of Sudan
Reducing pressure on the environment	<ul style="list-style-type: none"> ○ Percentage of forest area out of total land area ○ Percentage of degraded land out of total land area

Source: United Nations (2015)

It is essential to build the technical capacities of WEF Nexus networks and forums and to upgrade the integrated policy-formulation capacities of institutions affiliated with WEF Nexus sectors. It is pertinent to enhance the adoption of water use efficiency (WUE) tools and to promote the use of efficiency boosting devices and systems. The different stakeholders are requested to engage in the planning for sustainable aquifer management at a wider scale and to expand the coverage of the federal and state disaster risk management (DRM) authorities to other parts of the country.

It is important to develop networks that consolidate communication and outreach methods and tools for integrating the WEF Nexus sectors. Develop vertical and horizontal networks and introduce integrated work programs among different departments within the same ministry and within the state ministries and locality

offices. Invest in human capital to strengthen the planning and policy-formulation capacity of staff, and rural and farming communities; likewise, farmers can be trained in business and vocational disciplines.

Provide training in planning and policy formulation and introduce new technology to aid in data collection and analysis of rainfall, river flows, and supplies of water for agriculture. Establish databanks and software memory of seminars, workshops, studies, and other endeavors and provide vocational training and design of infrastructure for farmers and skilled labor. Farmers, water users' associations and skilled laborers must be trained in the management, operations and maintenance of water canals, pumps, sprinkler irrigation and water harvesting technologies.

Undertake joint research and studies on common water resource development methodologies and legal rights allocations, and strengthen applied research in the area of water harvesting.

Strengthen capacity building of human resources by reviewing existing staffing of departments and identifying opportunities to improve staff members' managerial and thematic expertise with respect to the Nexus approach. This would involve conducting a combination of capacity-needs assessments and a capacity-development program for the personnel across the different sectors. The capacity building should include regular training of staff on available courses offered by multilateral and bilateral development partners. The development program may include online training and webinars or hosting interns, graduate students or PhD candidates to allow for exposure to fresh ideas and additional human-resource capacity building. Several Arab centers are available and can support development in this respect (Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) and the Arab Water Council (AWC)). These organizations proved to be instrumental in the conceptual development of the WEF Nexus in the Arab region, providing concrete formulation and implementation programs for technical people. The programs also require the promotion and involvement of cross-sector research on Nexus topics related to current WEF institutions and working programs. These programs can help build on the existing sectoral strategies for water, renewable energy and sustainable food consumption and production.

There is a need to mobilize new financial resources and provide timely and adequate budget allocations to facilitate regular WEF operations while supporting sectoral agencies in achieving their mandates and services. The mobilization of funds and additional budgets will allow for the establishment of more water-harvesting projects to cope with growing demands for supplementary irrigation in rainfed areas. Similarly, it is important to establish water-harvesting communities to expand up-scaling of the system in large areas under rainfed conditions.

There is also a need to enhance the establishment of private-sector agricultural water and energy supply services and to provide training opportunities for private companies and farmers cooperatives in this area.

WEF capacity building requires:

- Enhancing capacity of staff in the respective technical committees.
- Strengthening institutional capacity within the three sectors for better integration and joint planning, giving more careful consideration to the cumulative and interrelated impacts of policies and regulatory regimes.
- Taking into account political and market forces in the form of subsidies, profit seeking and state agendas.

Capacity development needs and opportunities related to Nexus mainstreaming include:

- Strengthening the technical capacities on integrated approaches in the management and governance of WEF resources.
- Strengthening the technical capacities for designing and implementing coherent policies across sectors that promote a Nexus approach.
- Training of federal and state-level experts.

6.2.4 Knowledge, Database and databank Development Requirements for Mainstreaming the WEF Nexus in Sudan

The study identified the following knowledge, database and databank development requirements for mainstreaming the WEF Nexus in Sudan:

- Strengthen the institutional capacity for data and statistics surveys in the different WEF sectors. The existing level of data quality and data sharing has to be reviewed in order to propose appropriate methods for data collection, storing and retrieving for in-depth analysis and for future projection. Due consideration of groundwater resources is needed in order to tap the potential water resources in the Nubian Sandstone aquifers. Strengthen database of supply and demand measurements for energy, especially renewable energy (solar and wind), in remote areas inaccessible by the national grid. Detailed data on rainfall quantity and distribution is needed in the rainfed sector, which sustains almost 90% of Sudan's agriculture. Most crops are lost due to droughts, floods and dry spells during the short rainy season. Locality-specific data on rainfall, including volume, distribution and risks can support existing disaster-mitigation and risk-management efforts. The data for areas with sustainable groundwater resources will support permanent crop production, including the production of high-value crops such as vegetables and fruits, all year round.
- Existing knowledge and databases cannot support the formulation of short- and long-term plans and policies for WEF programs and activities at the federal and state levels in Sudan. Databases storing records of the supply and demand for water from seasonal streams, rainfall resources and groundwater are needed.
- Provide adequate funding to the water-energy and food-production and distribution sectors, and for education, training and research. This is needed to enable a review of the curricula at school and university levels, to ensure concepts associated with WEF Nexus resources management are included.

- Undertake joint research and studies on common water resource development methodologies and legal rights allocations, and strengthen applied research in areas of water harvesting.
- Another area that requires urgent attention and has WEF implications is the activation of the non-functional flood early warning system and the need to strengthen data reliability and to promote data sharing within and between countries.

WEF Nexus implementation needs a supportive policy environment and reliable, cross-sectoral data development and sharing.

- A Nexus approach requires political will at the highest level. Given that the Nexus approach is more complex than conventional sectoral management, there is a need to address, reduce and communicate this complexity and to develop capacity accordingly. Consolidation of data and methodologies of the Nexus approach has to stimulate the dissemination of the approach.
- Development of integrated databases and data/information management and analysis is a requisite of any Nexus approach.

7 PROPOSED NEXUS PROJECTS

The proposed Nexus projects are based on: consultations with experts at the Policy Dialogue and Nexus Training workshop that occurred at the end of October and in early November of 2018; discussions with staff from federal and state ministries; an assessment of invitation tenders presented for the preparation of assessment studies and feasibility projects by the Ministry of Water Resources, Electricity and Irrigation (MWREI) and the Ministry of Agriculture and Forests (MOAF) and concerned State Ministries; and finally, on the consultants' assessment of Nexus challenges and opportunities. The proposals were verified and assessed during the Khartoum Validation workshop with experts on February 19.

The following criteria were considered in the identification of projects and activities:

- 1) Projects with a Nexus Angle (i.e., related to water, energy and food resources and/or security)
- 2) Expressed need by stakeholders consulted in the policy dialogue, training and validation workshops as well as in the Key Informant Interviews
- 3) Projects that help address the key constraints identified as part of this analysis
- 4) Projects and activities that form part or directly relate to the strategies and plans of the key ministries concerned
- 5) Projects and activities that go beyond studies and are focused on interventions on the ground
- 6) Projects and activities that can be implemented within a reasonable amount of time (no more than three years following preparation)
- 7) Projects that cover different geographies within Sudan but also projects that have a regional character given the resource dependence and linkages as well as the geopolitical and regional agreements of Sudan, and
- 8) Projects that together cover a range of sectoral foci (i.e., food production, renewable energy and water security)

Figure 8 and Box 6 summarize the final set of proposed activities.

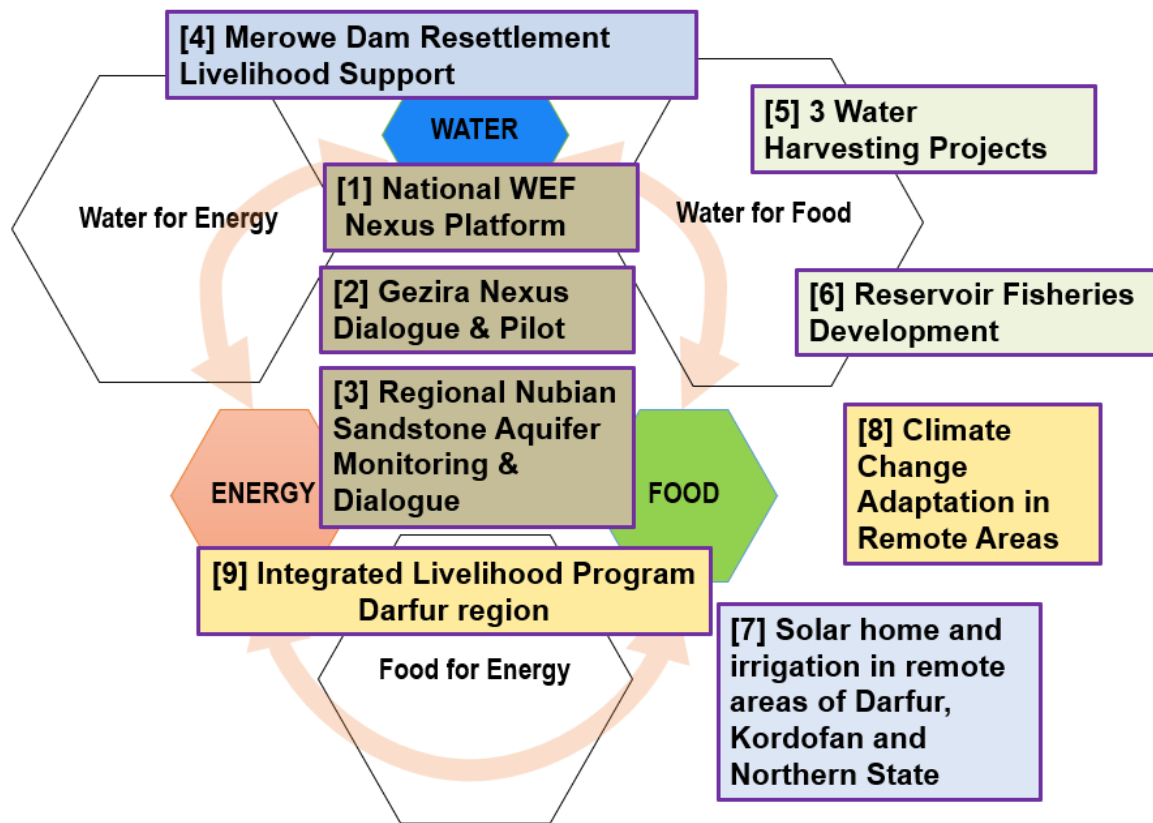


Figure 8: Summary of proposed projects and activities

Box 6: Summary of Nexus priority dialogues and projects

The dialogue comprised three institutional dialogue proposals, namely:

- Establishment of an integrated WEF sector and cross-sector platform
- Gezira Nexus Dialogue and Pilot
- Regional Nubian Sandstone Aquifer Dialogue and Monitoring

The investment projects comprise six investment projects, namely:

- Merowe Dam Resettlement Livelihood Support
- Water Harvesting Projects
- Reservoir Fisheries Development Project
- Solar Energy for Agriculture Project
- Climate Change Adaptation in Remote Rural Areas
- Integrated Livelihood Program, Darfur Region

Three of the proposed projects focus on institutional dialogues and six projects have a specific investment and intervention focus. The summary ranking of suggested projects as well as a series of additional activities proposed during the validation workshop is added as Annex 2 and Annex 3.

Of note, an originally proposed biofuel project using sweet sorghum was rejected during the validation workshop held on February 12, 2019. The key reason for the rejection is the potential conflict between water and land use for energy production versus water and land use for food production. A short summary of that project is included at the end of Annex 2. On the other hand, one of the projects proposed during the Validation Workshop was

added to the final set of proposed activities, specifically the project titled “Climate Change Adaptation in Remote Rural Areas”.

Moreover, one project was added outside the Validation workshop period, specifically project 9, “Integrated Livelihood Program, Darfur region”. This is a larger livelihood program already submitted by AOAD and was added for additional financial support and because it fits the Nexus lens.

Table 8 provides a summary description of the projects and the remaining sections introduce all proposed activities in detail.

Table 8: Summary of final set of proposed activities (dialogues and investment projects)

No.	Title	Location	Implementers	Proposed Budgets/Duration	Nexus Rankings
1	National WEF Nexus Platform	Nationally	MWREI, MOAF, MAR&F, IFPRI ,GIZ, FAO/AgWM, UNDP/GEF, RCREEE, RISEE, and others	\$150,000 (1 year)	F: +2 E: +2 W: +2 S: +2
2	Gezira Nexus Dialogue and Pilot	Gezira scheme	MWREI, MOAF, MOFEP, FAO, AgWM, IFAD, IFPRI, GIZ, and Bank of Sudan, Private sector and others	\$1,200,000	F: +3 E: +1 W: +2 S: +2
3	Regional Nubian Sandstone Aquifer Dialogue and Monitoring	Aquifer area underlying Chad, Egypt, Libya and Sudan	Gov, MWREI, MOAF, MOFEP, FAO, AgWM, IFAD, IFPRI, GIZ	\$1,200,000	F: +2 E: +1 W: +3 S: +3
4	Merowe Dam Resettlement Livelihood Support	Merowe Dam area, with broader implications for other dams with resettlement needs	State Ministry of Agriculture	\$1,500,000	F: +1 E: +2 W: +1 S: +1
5a	Blue Nile State Water-Harvesting Project	Blue Nile State	MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture and animal resources and physical planning, FAO/AgWm, IFAD	\$600,000	F: +2 E: +1 W: +2 S: +1
5b	White Nile State Water-Harvesting Project	White Nile State	MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture and animal resources and physical planning, IFAD, AfDB, GEF, UNDP	\$800,000	F: +2 E: +1 W: +2 S: +1
5c	Cross-State Khor Abu Habil Water-Harvesting project	South Kordofan, North Kordofan and White Nile states	Private sector operator in North Kordofan State, MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture, FAO/AgWm, IFAD	\$200,000	F: +1 E: +1 W: +2 S: +1

6	Roseires Reservoir Fisheries Project	At Roseires Dam	MWREI, MAR&F, State Ministries of agriculture and animal resources and physical planning, FAO/AgWm, IFAD, World Fish	\$200,000	F: +2 E: +0 W: +0 S: +1
7	Solar Home and Irrigation in Remote States	Darfur, North and West Kordofan	MWREI, MAR&F, MOFEP, State Ministries of agriculture and animal resources and UNDP/GEF, FAO/AgWm, IFAD, Private sector	\$300,000	F: +2 E: +3 W: +2 S: +2
8	Climate Change Adaptation in Remote Rural Areas	To be determined	Ministry of Agriculture, Ministry of Environment, University of Khartoum, NCR	\$300,000	F: +2 E: +2 W: +2 S: +2
9	Integrated Livelihood Program, Darfur region (5 states)	North, South, East, Central and West Darfur states	AOAD as lead, with State Ministries of Agriculture, Water Resources, Federal ministries of agriculture, livestock and water resources, locality governments, Federal ministries of agriculture, livestock, water, energy and irrigation, High Council for Environment and Natural Resources, WFP, UNDP, UNICEF, GIZ, NGOs and communities, agricultural bank and advisory services and inputs providers.	\$6.1 million (with various financing agencies involved)	F: +2 E: +1 W: +2 S: +2

Note: The Nexus Ranking uses the ICSU 2017 scale (see details in Annex 4).

7.1 Institutional Dialogue Projects

7.1.1 Project (1): National WEF Nexus Platform

- Budget: USD 150,000 for one year
- Potential Project Implementers: MWREI, MOAF, MAR&F, IFPRI, GIZ, FAO/AgWM, UNDP/GEF, RCREEE, RISEE, and others (Regional Center for Renewable Energy and Energy Efficiency and Research Institute for a Sustainable Environment Egypt)
- Linkages with other projects: Five-Year Plan Projects, JICA Revising MWREI Policies, AfDP/GEF, UNDP/GEF, NAPA, NAP, NBSAP, Nexus potential, ICARDA Land use maps of Sudan
- Project Category: Knowledge generation for water management/environmental protection/energy generation/ agricultural production
- Contribution to the 25-Year National Strategic Plan: Increase integration of WEF-sector activities to achieve sustainable development
- Contribution to the SDGs (2015-2030) related to WEF-sector development

National WEF Nexus Platform	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+2	+2	+2
Description of contribution	The platform allows technical experts to discuss and develop synergies; enables existing bridging institutions and mechanisms to promote WEF Nexus integration and coordination; avoids duplication of initiatives, identifies resource-use efficiencies and reduces trade-offs; uses ICT and other data-sharing devices to ensure WEF data are available to all sectors; develops and shares knowledge on Nexus solutions, including: climate-change-responsive WEF Nexus interventions and SMART WEF interventions			
Description of synergistic and mitigating measures	ICT measures can broaden the region beyond national ministries to state ministries			

Background:

The governance/control and management of water, energy and food is sectoral and is led by the three main ministries related to the WEF. The Ministry of Water Resources, Electricity and Irrigation leads planning and policy development around irrigation infrastructure and hydropower generation. The Ministry of Agriculture and Forests leads the planning and policy formulation of crop production and crop water management at the farm level. The Ministry of Oil, Gas and Minerals leads the planning and formulation of policy related to petroleum drilling and fossil-fuel supplies.

There are several ministerial committees that coordinate part or all of WEF-sector activities, such as the Higher Committee for Seasonal Crop Production, the Follow-up Committee of Agricultural Inputs and Finance, as well as the Agricultural Sector Ministerial Committee, including the state ministries of agriculture and the agricultural public corporations.

There is unanimous consensus among senior decision makers that existing senior inter-ministerial councils and committees have little or no role in integrating WEF sector-based programs and policies. These senior mechanisms engage in endorsing the programs presented to them with minor interventions and are keen to follow up their performance. However, the actual process of planning and policy design is undertaken by the technical staff in the individual sectoral agencies based on general guidelines issued by the senior councils and committees. The preparation of plans and policies at the sector ministers' levels takes place with minimal coordination and synergy. At the same time, there is no interaction among these technical staff. They produce sector-based programs and policies that require further merging and integration to remove conflicts and to ensure integration, synergies and reduction of trade-offs. The absence of synergies among line government agencies and ministries at the federal level and the vertical synergy between them and the states authorities and ministries at the state, locality and community levels has resulted in isolated implementation of the WEF programs and policies that may overlap or conflict with each other.

Moreover, organizational structures and mandates in the water, energy and agriculture sectors are duplicated and overlapping both at the federal and state levels. Coordination and consultation among federal, state and community partners, including women's groups, is critical to formulating and implementing viable WEF policies, strategies and plans. The absence of an institutional platform for the integrated formulation and management of WEF Nexus policies and plans results in sector-based and fragmented plans, policies and implementations.

Finally, although committees are found at the senior ministerial level there is still an opportunity for integrating such existing committees with cross-sector institutions at senior and technical levels. Thus, reorganizing, strengthening and enabling these **existing bridging institutions** and **mechanisms** will promote WEF Nexus integration and coordination to achieve sustainable development.

Background

- 3 sectoral ministries (Ministry of Water Resources, Electricity and Irrigation, Ministry of Oil, Gas and Minerals and Ministry of Agriculture and Forests) and a multitude of other stakeholders (Ministry of Finance, Bank of Sudan, private sector, local communities, etc.)
- Complexity of the WEF sectors and cross sectors
- Sector-based planning and policy formulation results in overlapping and sometimes conflicting objectives
- Multitude of high-level committees for synergy are short term and do not consider long-term strategic objectives

Objectives:

The objective of this proposal is to streamline the administrative structure and organization of the WEF Nexus so that it is more synergistic and integrated (information provided by the General Secretary for National Strategic Planning and in conformity with the recommendation of the Ex-Minister of Agriculture).

Objectives

- Enable existing bridging institutions and mechanisms to promote WEF nexus integration and coordination
- Avoid duplication of initiatives, identify resource-use efficiencies and reduce trade-offs
- Use ICT and other data-sharing devices to ensure WEF data are available to all sectors
- Develop and share knowledge on Nexus solutions, including: climate change-responsive WEF Nexus interventions and SMART WEF interventions

Description of the activity

The proposed activity has two components. The first component is to reorganize the institutions currently comprising the WEF sectors and cross sectors. The second component is to build the capacity of the institutions.

We propose establishing a dialogue between WEF Nexus authorities to reorganize the existing inter-ministerial committees into an appropriate platform mechanism for an integrated WEF Nexus. The composition of the Council will include the Water Council, the Agricultural and Livestock Council, the Oil, Gas and Minerals Council and the Sustainable Development Strategies Council. These councils are to supervise, guide and monitor the formulation, management and implementation of the supporting entities in an integrated manner. The supporting entities include the WEF coordination and implementation platform, the land-use and land-tenure platform, the research and technology transfer platform, the administration/financial platform and the legislations platform. Those platforms are expected to lead to an integrated WEF Nexus that also takes a forward-looking approach, taking into consideration adverse effects of climate change, as well as solutions such as integrated, smart WEF interventions. Consultation with government, civil societies, private sector and local communities and with legal and supervisory councils at the federal, state and locality levels is important. The gradual introduction of the WEF Nexus concept to be understood and adopted by the specialized stakeholders is also among the pertinent points to be taken into consideration.

As a first entry point for Nexus mainstreaming at the institutional level, the Strategic National Planning Council (SNPC) should lead the coordination process. The General Secretary for the SNPC indicated that they are already moving towards the coordination of all WEF sectors and associated sectors for optimum utilization and achievement of sustainable development within the context of climate change. The SNPC is expected to lead the coordination process to remove redundancies and overlaps among WEF sectors and cross-sector resources at the federal and state levels. This would be followed by institutional, policy and legislation reforms for WEF resources management.

Figure 9 provides an outline of the proposed Council Platform, which requires further discussion and improvement in order to become an applicable mechanism that can operate within the current limiting conditions of Sudan. The members of the platforms are to include all stakeholders at the federal, state and locality levels including the local communities and the private sector. The platform is supposed to have branches and networks between federal and state levels.

Description: (Component 1)

- Reorganization of existing inter-ministerial committees into an appropriate platform mechanism: WEF Nexus Council with Water Council, Agricultural and Livestock Council, the Oil, Gas and Minerals Council, and the Sustainable Development Strategies Council
- Supporting entities include WEF coordination and implementation platform, the land-use and land-tenure platform, the research and technology transfer platform, the administration/financial platform and the legislations platform
- Develop ICT and data-sharing mechanisms to ensure appropriate cross-sectoral information feeds into planning, upgrade know-how of technical staff to support policy and decision makers
- Platforms are expected to support integrated planning taking into consideration climate change and the drive for integrated SMART WEF interventions
- Benefits from German Sustainable Development Model.

The proposed mandates of the Council are to:

- Review cross-sector trade-offs and synergies of sector strategies, policies and action plans.
- Emphasize the economic efficiency and market mechanisms that convince the representatives of each WEF sector and the senior decision makers in the government to change their conventional modus of operandi and adopt the integrative elements of a Nexus approach.
- Account for social, economic, and environmental considerations when deciding on certain activities related to WEF-sector development and implementation in a balanced and sustainable manner.
- Create enabling conditions for WEF operations, including regulatory frameworks, market incentives, adequate finance and trade policies, and ongoing research and development.

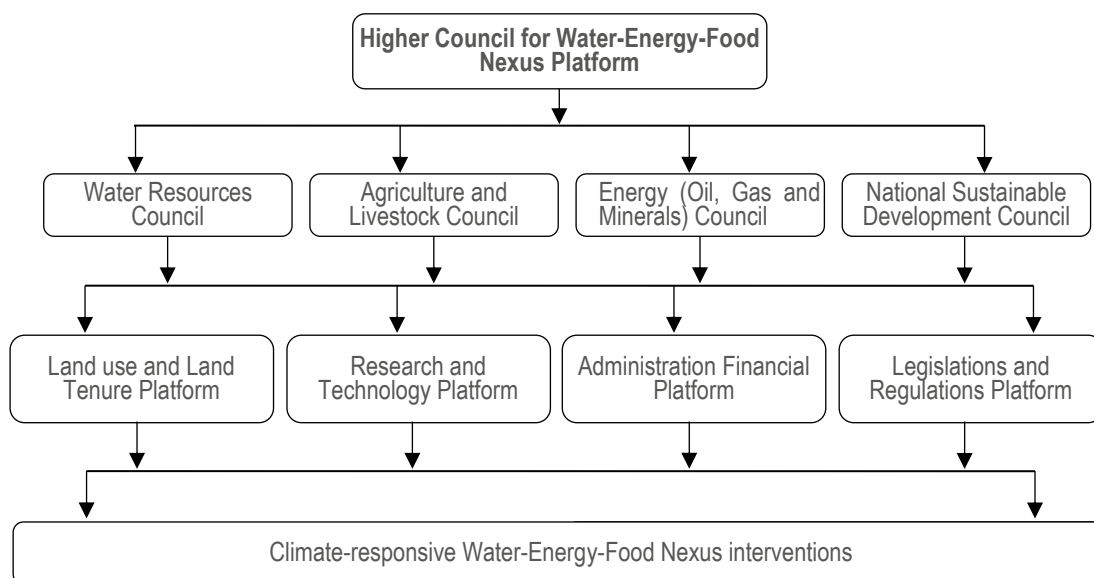


Figure 9: Proposed reorganization of coordinating higher council for WEF Nexus for integrated water, energy and food security development and utilization in Sudan

Description: (Component 2: Capacity Building)

- Carry out orientation programs to demonstrate advantages of a Nexus orientation over a single-sectoral mindset
- Strengthen national capacities for designing and implementing policy packages that facilitate and promote the adoption of a Nexus approach
- Training programs for staff to adopt joint studies, planning, policy formulation and management and monitoring activities
- Strengthen Departments of Statistics as an institution for providing cross-sector data on WEF inter-linkages and for providing integrated Information Management for mainstreaming the WEF Nexus
- Strengthen M&E systems for mainstreaming Nexus opportunities
- Integrated databases, as well as data/information management and analysis, for mainstreaming WEFNexus
- Strengthen staff communication and outreach capacity

Implementing organizations:

All the principal ministries directly related to WEF sectors, cross-sector government ministries and agencies, private sector and the targeted communities. The reorganization shall take place at both the federal and state levels.

Expected outcome:

An integrated and coordinated WEF Nexus mechanism for planning and policy formulation, implementation and follow up is established.

7.1.2 Project (2): Gezira Nexus Dialogue and Pilot Project

- Budget: USD 1,200,000 for 18 months
- Potential Project Implementer: Gov, MWREI, MOAF, MOFEP, FAO, AgWM, IFAD, IFPRI, GIZ, and Bank of Sudan, private sector and others
- Linkages with other projects: Rehabilitation of the Gezira Scheme (SDG 1,540 million), revitalization of the expansion of strategic crops in the scheme (cotton and wheat), Wheat National Project, Food Security Initiative, Agricultural and Water Research Projects
- Project Category: negotiations/efficient water and crop production management/environmental protection/energy generation/agricultural production.
- Contribution to the Strategic Plan: SDG Target 2 and WEF Nexus related targets.

Gezira Nexus Dialogue and Pilot	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+3	+1	+2	+2
Description of contribution	Improved production of food as a result of Nexus coordination	Reduction of energy waste on this highly energy-intensive scheme	Improved water security for everybody (food production, humans, and the environment)	Reduction of water and energy waste improve environmental sustainability
Description of synergistic and mitigating measures	Learning exchanges with irrigation schemes with similar biophysical conditions would be useful	Understanding energy linkages of irrigation in Gezira by, for example, using an energy checklist for irrigation would be useful	Understanding how the goals of both government and tenant farmers can be met without increasing water use would be an important synergistic activity	Understanding the current impacts of Gezira on the environment would be useful

Background

The Gezira Scheme, one of the largest irrigation schemes in the world, is of crucial importance to Sudan's national food security and its agricultural exports. The scheme extends over 840,000 hectares providing employment to 128,000 tenant farmers and 150,000 seasonal laborers. The scheme is irrigated by gravity from Sennar Dam through a network of irrigation canals totaling about 150,000 km. Total water consumption in the scheme and its surrounding extensions is about 9.3 billion cubic meters. The scheme used to grow cotton as the main crop in a structured crop rotation made up of cash crops for exports (cotton and groundnuts) and food crops for domestic consumption (sorghum and wheat (import substitute) and, at a more limited scale, vegetables, pulses and fodder crops).

Until 2005, a tripartite management system involved the Government of Sudan, the Sudan Gezira Board (SGB) and the tenants. The Ministry of Irrigation controlled the operation and maintenance of the dam and the canals from the dam down to the farms. At the same time, the SGB also centrally controlled the crop production and irrigation system at the field for decades. By 1992/93, and following a privatization policy, the Gezira Scheme sold out its agricultural capital assets (machinery fleet, ginning factory, railway services for transportation of cotton inside the scheme). With the endorsement of the Gezira Act in 2005, and following problems in cotton marketing and financing, the scheme policy shifted from a top-down controlled system of production into a system where anyone could grow what they wanted. As a result, tenants abandoned cotton and wheat and now grow preferred crops according to market signals. The area under cotton and wheat dropped drastically and farmers switched into growing sorghum and vegetables. The area cultivated under cotton declined from 420 thousand hectares in 1984/85 to less than 84 thousand hectares in 2013/2014. Similarly, the area under wheat dropped from 500 thousand hectares 1991/92 to just 75 thousand hectares 2013/2014.

In the new scheme, scattered areas were put under cultivation, leading to a disorganized and chaotic irrigation system and high costs for the provision and maintenance of the irrigation water and canals. Given the declining contribution of the Gezira Scheme to the national economy, the government is exploring several options for restructuring the scheme. Currently there are efforts to return to the old, top-down control system, which is largely opposed by the tenants. The proposed regulations would impose penalties upon tenants who do not comply with the crop-rotation system. To identify solutions that ensure improved food production, a more rational use of water, and associated energy inputs (fertilizer, pesticides, etc.), a coordinated Nexus Dialogue and pilot is needed. The dialogue would be linked with the pilot implementation of identified solutions that support both tenant farmers' aspirations and government needs for export and import substitution crops while improving, water, energy and food security. The proposed pilot would use ICT tools for enhanced communication between tenant farmers and the scheme operators.

- Gezira Act of 2005 allowed farmers to change from a cotton–wheat system to the cultivation of sorghum, vegetables and pulses → decline in FOREX earnings
- Switch from top-down to farmer-led cultivation was not supported with individualized, on-time irrigation water allocations → productivity and area declined
- Government tries to return to previous system

Objectives:

The project will use Nexus dialogues to clarify needs and demands of farmers, irrigation managers and the government across the WEF Nexus. It will then identify, develop and implement ICT tools that provide two-way communication between irrigators and irrigation managers to improve accountability and service delivery of irrigation managers for WEF security.

Description of the project:

- Establish dialogue to discuss trade-offs between the interest of the tenants and the national economy (gain or save foreign exchange earnings)
- Pilot ICT system to increase two-way accountability between irrigation service providers and irrigators to increase:
 - e) Water use efficiency
 - f) Farmers' incomes
 - g) Food security
 - h) Energy use efficiency
- Link pilot improved extension, credit and marketing services

7.1.3 Project (3): Regional Nubian Sandstone Aquifer Monitoring and Dialogue

- Budget: USD 1,500,000, 3 years
- Potential Project Implementer: Gov, MWREI, MOAF, MOFEP, FAO, AgWM, IFAD, IFPRI, GIZ
- Linkages with other projects: Food Security Initiative Projects, Nile Basin Initiative and GERD agreements, revitalization of the expansion of strategic crops in the scheme (wheat), Wheat National Project, FoodSecurity Initiative, Agricultural and Water Research Projects
- Project Category: negotiations/ efficient water and crop production management/environmental protection/energy generation/ agricultural production
- Contribution to the Strategic Plan: SDG Target 2 and WEF Nexus related targets.

Nubian Sandstone Aquifer Monitoring and Dialogue	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+1	+3	+3
Description of contribution	More sustainable management of the aquifer should improve regional food security	More sustainable management of the aquifer should limit future wastage of energy resources for pumping and support better energy planning	More sustainable management of the aquifer is essential for water security	More sustainable management of the aquifer is essential for environmental security
Description of synergistic and mitigating measures	An exchange with other trans-boundary aquifer-management programs could be added; challenges that would need to be mitigated include that at this point Egypt and Libya are large users of the aquifer while Chad and Sudan are not. Joint monitoring and management might well not be in the interest of the current large extractors. Finally, the situation in Libya would need to be carefully assessed.			

Background

Sudan shares a number of Non-Nilotic streams and ground water aquifers with neighboring countries. It shares the water resources of the Nubian Sandstone aquifer with Chad, Libya, and Egypt. It also shares the Azum and Hawar running surface streams with Chad and other neighboring countries. Sudan also shares common seasonal water resources on the border with South Sudan.

The Nubian Sandstone is believed to be based on water resources of fossil origin. The sedimentary Nubian sandstone formation aquifers extend to depths ranging from 40 to 400 meters and have total dissolved solids ranging from 100 to 2,000 ppm. Water is generally of fossil origin. The annual recharge of this groundwater is difficult to assess accurately but preliminary estimates suggest 2km³ and an annual abstraction of 1km³ (Table 9). As can be seen from

the table, the annual abstraction is less than 0.2% of the storage. Since most of the storage is of fossil origin, care must be taken in developing these resources in order to ensure sustainability.

Table 9: Groundwater Storage, Recharge and Abstraction in Sudan (Km3)

Aquifer	Nubian sandstone basins
Groundwater storage	503,000
Annual recharge	1,000
Annual abstraction	700

Source: SNCIHP (2000)

There is not yet a permanent legal and institutional cooperation agreement among the four countries sharing the aquifer. There is only a Joint Authority for the Study and Development of the aquifer, which was started between Egypt and Libya in 1991; Sudan joined in 1996 and Chad in 1999. At this point, almost all aquifer resources are solely used by Egypt and Libya. However, the only instrument on record regarding the Joint Authority is an internal regulation describing the structure, functions and decision-making processes of the Authority. There are no provisions regarding the management of the aquifer or the groundwater.

Nexus

- No rules about the management of the shared Nubian Sandstone Aquifer exist.

Objectives - General

The general objective is the promotion of regional cooperation, networking, monitoring, and implementation mechanisms with neighboring countries to facilitate equitable and fair sharing of supplies of adequate water for food production based on mutual benefits of partners sharing the common water resources.

Objectives - Specific

- Dialogues and technical studies to understand Nexus issues around the Aquifer
- Install 20 groundwater monitoring wells with automatic readings of groundwater depth and information accessible to all 4 countries to support cross-country and cross-sectoral monitoring
- Develop principles for aquifer use.

Description of the Program:

- Design a strategy for cooperation, networking, monitoring, and implementation mechanisms (integrate water resources into production activities based on competitive and comparative advantages and opportunities).
- Set up regular monitoring of the uses and withdrawal within the acceptable limits; data are to be linked with renewal or rejection of the pumping licenses.
- Set up management principles and to guide usage of the fragile groundwater resources.
- Develop database to store information on potential crop types and livestock and technology investment opportunities

7.2 Investment Projects

This section draws on the Five-Year Economic Reform Program (FYERP) (2015-2019). The FYERP presented projects in the realm of the WEF sector intervention area, such as the construction of Kajbar and Sheraik Dams and the rehabilitation of irrigated schemes. Some of the new projects are those related to the introduction and expansion of solar and wind renewable energy sources.

The proposed projects identify areas of intervention in certain cases that meet emerging situations as proposed by the respective participants in the training and validation workshops.

7.2.1 Project (4): Merowe Dam Resettlement Livelihood Support

- Budget: USD 1,500,000 for solar energy (home and irrigation) for Merowe affected farmers
- Potential Project Implementer: State Ministry of Agriculture
- Linkages with other projects: All projects concerning dam construction (Rosaries Dam, Upper Atbara and Setit Dam pipeline resettlement projects)
- Project Category: Capacity building or knowledge generation for climate change adaptation, Capacity building or knowledge generation for water management, Capacity building or knowledge generation for environmental protection, Land reclamation or reforestation
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets.

Merowe Dam Resettlement Livelihood Support	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+1	+2	+1	+1
Description of contribution	Improved food security through increased livelihood opportunities of the dam-affected population	Increased energy security through solar roof top access	Increased livelihood opportunities facilitated by clean energy access promoting water security	Clean energy access improves environmental sustainability
Description of synergistic and mitigating measures	Increased income and access to clean energy can also increase food production in the area	Clean energy from solar can help generate a series of off-farm employment opportunities		Improved livelihood opportunities may or may not improve environmental sustainability

Background:

Sudan has constructed and will continue to construct new dams that have adverse effects on those people who were originally living on land selected to be dammed. The MWREI provides compensation and subsidies and supervises implementation of resettlement programs for two to three years. The responsibility of such programs is then transferred to the concerned state governments.

The primary objective of Merowe Dam is the generation of hydropower with a secondary objective of irrigation. The hydropower generation would support the electrification of the agriculture schemes in the country, changing diesel-pump schemes into electric-pump schemes. As a result, cost of irrigation would decline and the competitiveness of Sudanese crops in the export and domestic markets would improve. The construction of the dam was also expected to improve the livelihood of the displaced people and the communities in the two states inside and outside the dam command area, increasing the potential for animal drinking water and other related social services and benefits.

However, the construction of Merowe Dam did not lead to substantial benefits for resettled people or for other affected communities. Electricity services for agriculture were also not developed to the level originally envisioned.

- Merowe Dam affected water, energy and food security as well as environmental sustainability of those affected by construction
- This created a series of challenges to the livelihoods of resettled communities and those that did not move away from the dam
- Many of these communities lack of access to clean energy.

Objectives of the project:

- Develop resettlement guidance informed by Nexus thinking
- Strengthen agricultural managerial capacity of displaced people and the communities living within the dam command area
- Enhance the employment opportunities for local men and women
- Install solar-energy rooftop and irrigation systems to compensate for shortage of the electricity supplied by the dam
- Rehabilitate the negative effects of the dam on the microclimate of the domain area.

Description

The project would include the following activities:

- Implement a Nexus dialogue across dam operators, farmers, and water providers involving stakeholders affected by Merowe Dam
- Assess the impact of Merowe Dam on the livelihoods of resettled populations and on those that live within the command area of the dam

- Investigate the effect of the dam on groundwater recharge, water pumping, vegetative cover, biodiversity and the local microclimate
- Install solar irrigation and solar rooftop systems to alleviate acute access to clean energy in affected areas
- Develop resettlement guidance informed by Nexus thinking for future dam construction in Sudan

Expected outcome:

The expected results of the project shall identify the positive and negative impacts and recommend measures and mechanisms to minimize, mitigate or eliminate the negative effects and ensure the sustainable viability of livelihoods in communities affected by Merowe and other dams in Sudan.

7.2.2 Project (5a): Blue Nile State Water Harvesting

- Develop resettlement guidance informed by Nexus thinking
- Budget: USD 600,000 for rehabilitation and establishment of water-harvesting projects in the Blue Nile State
- Potential Project Implementer: MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture and animal resources and physical planning, FAO/AgWm, IFAD,
- Linkages with other projects: All projects concerning water harvesting in the country
- Project Category: Land reclamation or reforestation
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets.

Blue Nile State Water Harvesting Project	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+1	+2	+1
Description of contribution	Fodder, food, animal fattening	Reduction of groundwater pumping	Improved local water security	Improved vegetation
Description of synergistic and mitigating measures	The specific synergistic benefits will depend on the uses that the local population will put the Hafirs to. Any new local conflicts could put the investment at risk.			

Background

The Blue Nile State has diversified water resources composed of rainfall, surface and groundwater sources. The surface water resources come from within state boundaries and from the Ethiopian highlands. The three large khors (seasonal watercourse) arising from the Border Mountains and Ingessina Mountains are Khor Dunia, Khor Al Samaa and Khor Timit ().

Table 10).

Table 10: Water flow estimates of three major khors in the Blue Nile State

Khor	Annual rainfall(mm)	Annual water(mcm)	Drainage area (km ²)
Dunia	730	76	550
Al Samaa	800	380	1890
Timit	800	280	1410

Source: Blue Nile State Ministry of Agriculture, 2015

Civil conflict accompanied by weak agronomical operations limited the utilization of these resources resulting in low crop productivity and production in the rainfed areas in the state. Rainfall in Blue Nile State is sufficient to expand

water-harvesting activities, spread pasture seeds, and grow forests to increase the vegetative cover and provide good pastures for livestock grazing. Water harvesting would also support the environment and increase local water security.

In 1953-1965, ten stock routes hafirs (rainwater harvesting structures) were dug. Several of these have since deteriorated (hafir Fashar and Khor Al Telaih), or have been planted with crops (Hafir Madar), or incorporated into residential areas (Hafir Gerawa number 1 and Hafir Bek number 1) or have lost their function due to lack of regular maintenance (Hafir Al Geraid and Al tailab).

- Civil conflict has limited the use of water resources and the productivity of agriculture
- Many hafirs constructed during 1953-1965 are degraded, destroyed or idle

Objectives:

- Reduce energy used for pumping through groundwater recharge
- Improve water and food security through increased water availability
- Improve livestock productivity
- Increase water-use efficiency

Description:

- Establish rainfall water-harvesting system for human and livestock consumption and irrigation of crops (surface dams, deep bore wells, dikes)
- Rehabilitate four degraded hafirs
- Dig three new ones to supply drinking water to returning livestock from the South
- Provide veterinary services
- Provide fodder and grow pastures in the area
- Store dry hay bales for summer

Expected outcome:

The expected outcome is livestock settlement and increased crop production areas, fodder production for livestock grazing, improved water quality, and women's participation in the benefits of water-harvesting systems.

7.2.3 Project (5B): White Nile State Water-Harvesting Project

- Budget: USD 800,000 for water harvesting and livestock route
- Potential Project Implementer: MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture and animal resources and physical planning, IFAD, AfDB, GEF, UNDP
- Linkages with other projects: All projects concerning water harvesting in the country
- Project Category: Land reclamation or reforestation
- Contribution to the Strategic Plan: Increase of the revenue of households, food security, SDG Target 2 and other WEF Nexus targets

White Nile State Water Harvesting Project	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+1	+2	+1
Description of contribution	Fodder, food, animal fattening	Reduction of groundwater pumping	Improved local water security	Improved vegetation
Description of synergistic and mitigating measures	The specific synergistic benefits will depend on the uses that the local population will put the Hafirs to. Any new local conflicts could put the investment at risk.			

Background:

After the split of Sudan into Sudan and South Sudan, about 10 million heads of livestock were prevented from seasonal grazing in South Sudan. Large numbers of livestock returned to their originating sites in Sinnar, Blue Nile and the White Nile states, creating pressure on the land and water, especially during the dry season.

The White Nile State selected the Mikg Dam commanding area, neighboring a principal stock route in Al Salam and Al Jabalain localities, to accommodate the returning animals. The area receives annual flows but at a slow speed that will not irrigate land unless captured by a soil-constructed dam.

- Split of South Sudan drove back millions of livestock which used to graze seasonally in the South
- The returning livestock created pressure on drinking water resources and led to conflicts with farmers in the White Nile State
- The livestock were kept in limited areas depending on purchased fodder and water supplies

Objectives:

- Supply drinking water for humans and livestock
- Reduce friction between crop and livestock livelihoods
- Use supplementary water for irrigation
- Use added crop residues for biogas

Description:

- Increase the Mikg water-harvesting dam storage capacity in Al Salam Locality
- Construct hafirs in the two localities to provide drinking water for humans and livestock that cannot return to South Sudan for grazing
- Each hafir is about 50,000 cubic meters.
- Establish rainfall water-harvesting system for human and livestock consumption and irrigation of crops (surface dams, deep bore wells, dikes)
- Provide veterinary services
- Provide fodder and grow pastures in the area
- Store dry hay bales for summer

Expected outcome:

This project is expected to improve food security and promote desert control strategies. It would improve socio-economic livelihoods of the rural communities, combat the effects of drought and supply enough drinking water for humans and livestock providing them security and refuge while addressing the challenge of closed grazing routes in South Sudan.

7.2.4 Project (5C): Cross-State optimization of Khor Abu Habil Water Harvesting Project

- Budget: USD 200,000 for soil moisture sensors, inter-state Nexus dialogues and other associated investments
- Potential Project Implementer: Private-sector operator in North Kordofan State, MWREI, MOAF, MAR&F, MOFEP, State Ministries of agriculture, FAO/AgWm, IFAD
- Linkages with other projects: All projects concerning water harvesting in the country
- Project Category: Land reclamation or reforestation, water use improvement project
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets

Cross-State Khor Abu Habil Water Harvesting Project	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+1	+1	+2	+1
Description of contribution	More equitable generation of food production	Reduction of groundwater pumping	Improved water security in South Kordofan and White Nile States	Improved vegetation
Description of synergistic and mitigating measures	The specific synergistic benefits will depend on the specific uses of the additional waters in South Kordofan and White Nile States			

Background

Khor Abu Habil is a seasonal stream that rises in the Nuba Mountains and flows down through the three states of South Kordofan, North Kordofan and the White Nile. In North Kordofan, Khor Abu Habil Scheme was established in 1945 and rehabilitated in 1990 by the FAO to grow cotton, sorghum and vegetables in an area of 8,000-10,000 feddans. However, with rising debts due to poor marketing capacity and the rising cost of water-supplying services, the private sector stepped in to provide farmers with agricultural credit, inputs and services through a contract-farming system. The new intervention led to the widening of the storage dams in the state.

Both South Kordofan State and the White Nile State are not utilizing enough of the Khor stream for their farmers. Farmers in both states lack the financial and technical capacity or support to benefit from the running water stream. The WEF Nexus is raising the issue of interstate coordination and management of the water resources in a sustainable manner to create a win-win situation for the three states altogether.

- Fledgling water-harvesting project in North Kordofan State that recently received support from the private sector for increased production and storage expansion
- Increased abstractions in North Kordofan State affect both South Kordofan State and especially the White Nile State

Objectives:

- Implementation of upstream / downstream Nexus dialogues across the three states to identify measures for mutual increase in water-use efficiency and food security, for example, through the introduction of water scheduling tools, such as soil moisture sensors
- Possible extension of private-sector activities from North Kordofan to South Kordofan and White Nile states

Description of the Project

- Set up mechanisms to distribute the interstate seasonal flow of Khor Abu Habil equally among the three states
- Develop a program that increases water storage to satisfy the needs of the small farmers in all three states
- Scale up the contract-farming model in the states by providing credit, inputs, agricultural services and marketing to the farmers in the area

Expected outcome:

Private-sector involvement in SMART partnership with local communities is encouraged. A more equitable allocation of the water resources in the Khor will improve food security, water security and environmental sustainability and will reduce the need for pumping groundwater and thus save precious diesel resources.

The case of Khor Abu habil raises the issue of interstate management of a shared water supply system – one that needs storage to be sustainable – among the three states of South Kordofan, North Kordofan and the White Nile. The WEF Nexus intervention is to look for alternatives that take into consideration an integrated approach for managing this common water resource for the mutual benefit of the communities in the three states in the form of sustainable food security and poverty alleviation.

7.2.5 Project (6): Roseires Reservoir Fisheries Projects

- Budget: USD 200,000 for piloting and capacity building and provision of equipment and logistics
- Potential Project Implementer: MWREI, MAR&F, State Ministries of agriculture and animal resources and physical planning, FAO/AgWm, IFAD, WorldFish
- Linkages with other projects: All projects concerning Fish Development in the Five-Year Reform Plan (2015-2019)
- Project Category: Capacity building or knowledge generation for water management, Capacity building or knowledge generation for environmental protection, Food and nutrition security project
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, enhanced water management
- SDG Target 2 and other WEF Nexus targets.

Roseires Reservoir Fisheries Project	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	0	0	+1
Description of contribution	Fish is an important protein in the region	The goal will be to leave hydro-electricity production unaffected while balancing fisheries' needs with hydro-electricity and irrigation needs		Management of the reservoir for multiple purposes should not adversely affect the environment and could lead to a reduction of over-extraction of fish from other sources
Description of synergistic and mitigating measures	Transportation of fresh fish could be supported by solar-supplied transportation unless fish are dried	Cheap electricity for processing could support the project		

Background:

In Sudan, fish capture takes place around the River Nile and its tributaries, on man-made lakes and in the territorial waters of Sudan on the Red Sea. The estimated capture of fish was about 34,000 tons in 2012; 29,000 tons from inland waters and 5,000 tons from marine sources. The aquaculture sector is still in its infancy and annual production was estimated at 2,000 tons in 2012.

Man-made reservoirs are found in Jebel Aulia Dam, Sinnar Dam, Roseires Dam, Merowe Dam, Khashm El Girba Dam, and the Complex of the Upper Atbara and Lake Nubia on the border with Egypt. These dams host fish that are exposed to considerable seasonal fluctuations, mainly including changes in water level due to hydro-irrigation trade-offs. The Roseires Dam has full water storage in September/October that recedes during February-May. The peak fishing activity is during May-August. During the peak period, about 42.5% of the annual catch is collected.

The anglers' community in the Roseires Dam area is deficient in fishing gear, marketing facilities and services. The fishing sector lacks policies, laws and regulations, production, processing and marketing management, infrastructure and logistics, investments and financing, capacity and training. Therefore, this is an area for intervention using a WEF Nexus approach.

- Low or no fisheries production in reservoir lakes
- Low food and nutrition security

Objectives:

- Revitalize fishing activities of small producers in Roseires reservoir lake
- Increase WEF uses of Sudanese reservoirs
- Increase food and nutrition security

Description

- Optimize fishing activity in the lake and surroundings
- Supply fishing unions with improved boats and fishing nets
- Support marketing capacity of anglers
- Establish a cooperative cooling facility, marketing hall and union activity center
- Improve transportation technology
- Provide capacity building for upgrading the skills of the fishermen
 - Support fishermen with offices, equipment and logistics
 - Training in fish production, processing and marketing
 - Training in bookkeeping, operating bank accounts and in group dynamics for better union operations and management

Expected outcome:

Fisheries production is technically and economically feasible in the existing dams in Sudan and the incomes of small fisher folks can be supported.

The case of fisheries in the reservoirs in Sudan centers upon an issue that relates to the optimum utilization of idle resources for increasing the income of anglers and supporting women who are processing the fish. The problem lies in striking a balance between the opening and closing of dams and disrupting the natural multiplication process of fish. The long run of dams ending life cycle is also presented for discussion. The training of anglers and their organization into productive marketing associations is also another angle for consideration. A WEF Nexus problem of management, capacity building, and planning and data availability is presented for a solution.

7.2.6 Project (7): Solar home and irrigation in remote areas

- Budget: USD 300,000 for each state for conducting feasibility study and installing solar pumps in Darfur and North and West Kordofan States
- Potential Project Implementer: MWREI, MAR&F, MOFEP, State Ministries of agriculture and animal resources and UNDP/GEF, FAO/AgWm, IFAD, Private sector
- Linkages with other projects: All projects concerning introduction of solar energy pumps in Sudan in the Five-Year Reform Plan (2015-2019)
- Project Category: Capacity building or knowledge generation for climate change adaptation, Capacity building or knowledge generation for water management, Capacity building or knowledge generation for environmental protection, Land reclamation or reforestation
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets.

Solar home and irrigation in remote areas	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+3	+2	+2
Description of contribution	Improved production of food as a result of access to better pumping technologies and potentially cold storage for perishable crops	Access to clean energy	Improved water security through improved pumping	Reduced GHG emissions, reduced use of alternative energy sources with potential adverse health impacts
Description of synergistic and mitigating measures	Food trade options should be assessed	The livelihood possibilities associated with clean energy access should be explored		Other environmental impacts should be assessed as well

Background:

The solar-energy project is conceived as an available alternative source of renewable energy that can be used to replace diesel pumps in agriculture and drinking-water supply services and for lighting purposes, especially in remote rural areas inaccessible to the national grid. The Ministry of Water Resources, Electricity and Irrigation is embarking on a large-scale project for introducing solar energy into nine states including the Northern, North Darfur, Central Darfur, South Darfur, West Darfur, East Darfur, Blue Nile, South Kordofan and West Kordofan states.

The Ministry, in collaboration with the State Ministry of Agriculture and a Bank Consortium, has already started implementing a project in the Northern State installing 1,440 solar pumps for farmers on concessional credit. These solar pumps will replace diesel pumps in seven localities, supporting agricultural production in both the winter and summer seasons. Based on the success of this project the expansion of the solar pumps is targeted to cover at least 25,790 farmers already operating diesel pumps in the state. The high-value crops grown in the state justify the viability of the project, as farmers will be able to repay loans meeting the high cost of the solar pump installation in just a few years. Farmers grow perennial crops, wheat, broad beans, white-beans, fennel, garlic, fenugreek and potatoes, tomatoes, onion, sorghum, okra, maize, watermelon, cucumber and fodder. The perennial crops include alfalfa and date palm.

This case raises the issue of expanding solar-energy systems in large areas in Sudan, which will incur a high initial capital cost for the installation of the system. Such a high cost will not be affordable for the majority of the communities in dire need of such services. A WEF Nexus is raised here to provide recommendations for the mechanism of introducing this renewable energy source into poor areas that lack the credit worthiness and perhaps do not have the natural resources that support the production of high-value crops like those found in the Northern state.

- Lack of access to clean energy in Darfur, Kordofan and White Nile states affects water, food and energy security

Objectives

- Use flexible solar panels for multiple purposes (i.e., irrigation and lighting for homes)
- Support development of on-farm and off-farm small enterprises

Description of the project

- Development of a mechanism for distribution of solar pumps among small farmers and households
- Provide credit on soft terms to enable the farmers and households to buy the solar pumps
- Identify key on-farm and off-farm uses of flexible solar panels
- Design and support the production of a viable crop-mix portfolio that generates income for the small farmers and households to pay for the solar-pump credits

Expected outcome:

Wide-scale application of solar energy in agriculture and lighting services in remote areas, especially in Darfur, Kordofan, the White Nile and the Northern states can improve water, energy and food security and environmental sustainability.

Introducing the solar energy system in remote rural areas in Sudan reduces the dependence on the high-cost diesel energy imported with foreign currency. The problem with the installation of the solar energy system is the initial capital cost is unaffordable for many of the poor communities in dire need of this service. The problem raised is to look for a WEF nexus mechanism that facilitates the expansion of the solar system services in the remote areas in a technically and economically feasible and sustainable manner.

7.2.7 Project (8): Climate Change ADaptation in Remote Rural Areas

- Budget: USD 300,000 for each implementation
- Potential Project Implementer: Ministry of Agriculture, Ministry of Environment, University of Khartoum, NCR
- Linkages with other projects climate change adaptation projects
- Project Category: Capacity building or knowledge generation for climate change adaptation,
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets

Solar home and irrigation in remote areas	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+2	+2	+2
Description of contribution	Improved stability of food production as a result of reduced exposure to adverse climatic events	Access to clean energy	Improved water security through improved pumping	Reduced GHG emissions, reduced use of alternative energy sources with potential adverse health impacts
Description of synergistic and mitigating measures				

Background:

Climate change is a growing threat in Sudan. Using a community-focused and community-driven approach, this project will focus on generating climate resilience through adaptation that includes an increased focus on women’s empowerment and nutrition combined and facilitated with improved access to solar energy.

This is an intervention for women's empowerment. It includes the following Nexus elements: Water management (family storage tank), solar energy (for water pumping), food security (growing of vegetables, fattening of small ruminants) and environmental protection; the project is VC style.

- Climate change is a growing threat in Sudan and communities need to actively focus on adaptation to this threat.

Objectives

- Focus on community-based solutions to climate change
- Focus on women's empowerment
- Support crop diversification
- Provide access to solar energy

Description of the project

- Provision of solar rooftop systems
- Implementation of measures that support women's and men's decision-making over livelihoods and food production
- Introduction of an improved set of diversified crops and kitchen gardens
- Introduction of nutrition training
- Community-led identification of climate change adaptation options

Expected outcome:

This type of project has already been shown to be successful by improving livelihood options and food security in at least one community of Sudan and can be up-scaled following further piloting.

7.2.8 Project (9): Integrated Livelihood Program in Darfur Region

- Budget: USD 6.1 million as part of a multi-donor effort (other proposed donors: OPEC fund for international development, GIZ, WFP, AOAD)
- Potential Project Implementer: lead: AOAD; others: State Ministries of Agriculture, Water Resources, Federal ministries of agriculture, livestock and water resources, locality governments, Federal ministries of agriculture, livestock, water, energy and irrigation, High Council for Environment and Natural Resources, WFP, UNDP, UNICEF, GIZ, NGOs and communities, agricultural bank and advisory services and inputs providers.
- Linkages with water harvesting projects, solar roof top and irrigation activities and climate change adaptation in remote rural areas projects
- Project Category: Food security projects, Energy security and water management,
- Contribution to the Strategic Plan: Increase of the revenue of the households, food security, SDG Target 2 and other WEF Nexus targets.

Integrated livelihood program Darfur region	Food Security	Energy Security	Water Security	Environmental Sustainability
Nexus Ranking (-3 to +3)	+2	+1	+2	+2
Description of contribution	Improved stability of food production because of irrigation and other investments (market access, livestock management, etc.)	Use of solar for water management	Improved water security through various water investments, such as water harvesting	Reduced GHG emissions, more sustainable use of natural resources
Description of synergistic and mitigating measures		Solar could also be used to meet other energy goals, such as lighting	If irrigated area becomes too large, water scarcity and degradation might occur	

Background:

The Darfur region is a predominantly rainfed area characterized by insufficient and erratic rainfall. It has experienced several drought cycles in recent decades. The average annual rainfall varies from less than 100 mm in the northern parts of the Darfur States to more than 1000 mm in the southern and western parts (south Darfur and Jebel Marra). The amounts of rainfall in this region are highly variable and poorly distributed, causing excessive runoff, frequent dry spells and droughts. Rainfall in Nyala, for example, has a coefficient of variation of 39.7 while in El Fashir it is 34.7. Crop production in most areas suffers from low productivity caused by a number of factors. Among these are the:

1. Use of traditional agricultural practices
2. Unreliability of rainfall, environmental degradation and desertification conditions
3. High dependence on rainfed agriculture, which is highly sensitive to climatic change
4. Lack of extension services and access to technology and effective production means and tools
5. Lack of access to adequate capital and financing to adopt production-improvement technologies
6. Low soil water infiltration due to topographic features and uneven temporal and spatial distribution of rainfall

7. Poor awareness and lack of technical exposure of farmers and agro-pastoralists to techniques of harvesting the available rainfed water reserves, and a lack of knowledge and experience concerning agricultural water management (AWM) practices during periods of scarcity (CAWMA, 2007).

Due to inadequate adoption of sustainable agricultural intensification technologies, communities have opted to open up new areas for farming under the usual rainfed regime. This trend is increasingly becoming a source of conflict and a major threat to natural resources, undermining the ecological integrity of the region's natural resource base.

- Integrated development options, particularly for water resources management, under poor climatic and other conditions are lacking.

Objectives

- Post-conflict restoration and development of rural livelihoods, especially among women
- Transformation of vulnerable traditional rainfed production system from subsistence to a sustainable and market-oriented system
- Increase agricultural productivity and food security and income of smallholder farmer households by fully utilizing available water through the adoption of appropriate agricultural water management (AWM) improvement technologies and innovations
- Improve the resilience of pastoralists and agropastoralists and enable capacities including livestock routes, water points and veterinary services and supplementary fodder supplies

Description of the project

The project proposes to use the agricultural innovation systems platform approach. This entails identification and implementation of water-resource-supply technologies and innovations suitable for their settings, allowing for their increased adoption and up-scaling. Thus, this project will focus on Climate Smart Agriculture Landscape (CSAL) approaches to achieve improved food security and rural livelihoods as well as climate-change adaptation and mitigation. It operates on integrated management principles at the landscape (watershed) level, farm level and value-chain level.

The project will benefit from the Agricultural Research Corporation - Water Harvesting Research Institute (ARC-WHRI), MoWRIE, and the Ministry of Agriculture "Integrated Solutions to Agricultural Sector Program" already implemented across 18 States including Darfur. It will also benefit from the emerging lessons and success stories from similar previous development projects – mainly those demonstrated by FAO, IFAD, UNDP-NAPA and the AOAD.

The project will also draw on and expand positive results from demonstrations that have harnessed surface runoff in conjunction with groundwater resources in Darfur and other parts of the country and that have significantly improved yield and incomes of poor farmers. Since agriculture is the mainstay of the rural economy, these interventions can have a very high impact.

The project will focus on diversification of agricultural water management options within greater Darfur and the use of innovative approaches in availing technologies and information to the target groups in the selected sites and landscapes. The focus will not be limited to rainfed areas but will include small-scale irrigation areas as well.

In most of these sites, common agricultural value chains are based on cereals, high-value crops (citrus, vegetables) and livestock (dairy, and fattening) which may be enhanced through utilization of best-fit technologies.

Program components and activities:

The program addresses seven components of agricultural water development: reduction of crop losses, dairy production and the food-for-assets program, provision of inputs, capacity building, and rehabilitation and sustainable management of natural resources. The activities to be conducted are structured around four key outputs:

1. Gender-responsive agricultural improvement technologies and innovations demonstrated, adopted and up-scaled;
2. Improvement of stakeholders' capacities for adopting sustainable agriculture improvement technologies;
3. Adoption of policy options and institutional arrangements and regulations that closely link the national water-harvesting program to plant production; and strengthening of market linkages and promotion of value addition; and
4. Knowledge on sustainable water and food security improvement utilized.

Thus, the project will use an integrated combination of socio-bio-economic strategies that are gender sensitive as viable options towards lifting these low yielding, agro-ecosystems to higher yet long-term productivity levels.

Component 1: Agricultural water development:

- Conducting surveys for identification of potential water harvesting areas
- Provision and installation of solar powered irrigation system, where plausible in the other components
- Monitoring and evaluation

Component 2: Dairy Production Improvement Project in South Darfur

- Introduction of hybrid cattle into farms around the cities in South Darfur along with provision of health and feeding
 - Establishment of artificial insemination unit
 - Provision of semen
 - Availing of mobile units for artificial insemination
- Improving levels of food security, per capita income, standard of living and health status of citizens
- Creation of job opportunities for youth of both sexes
- Training at the level of trainers (TOT) for veterinarians and animal production specialists in artificial insemination

Component 3: Reducing Post-Harvest losses:

- Provision of storage facilities (hermetic bags and plastic silos)
- Institutional capacity building on post-harvest treatments
- Formation of farmers groups and associations
- Private-sector involvement in agricultural production and marketing

Component 4: Food for Assets with special emphasis on capacity building on water harvesting techniques.

- Training on construction/rehabilitation of water reservoirs and check dams
- Assistance in rehabilitation and construction of terraces
- Availing suitable supporting services including roads rehabilitation to improve accessibility to services
- Linking farmers to the nearby markets

Component 5: Provision of agricultural inputs to farmers for enhancement of productivity in Darfur region:

- Provision of improved seeds, seedlings, fertilizers and pesticides package
- Provision of simple agricultural machinery and equipmen.
- Awareness raising, and capacity building-program oriented to farmers and extension workers
- Provision of TOT training courses on the best agricultural practices

Component 6: capacity building to improve the efficiency of animal health service providers in the region:

- Training of trainers in the fields of diagnosis of endemic and epidemic diseases
- On-job training for technicians
- Provision of suitable veterinary services for better protection, production and productivity of farm animals
- Training on good health practices and preventive measures
- Training on quality control measures and good manufacturing practices
- Rural women empowerment in milk processing

Component 7: Rehabilitation and sustainable management of natural pasture in Darfur States:

- Conducting detailed surveys and studies for the degraded pastoral lands to provide adequate setup for the rehabilitation and protection of pastoral resources in project area
- Securing tractors and scrapers to open fire lines (fire prevention lines) *to increase* the productivity of pastoral areas in the region
- Collection and distribution of seeds and seedlings for rehabilitation of the degraded pastoral areas for the enhancement of pastures and open rangelands through availing seeds and seedlings of suitable grazing plants
- Training on integrated rangeland management systems to avail awareness raising and training on sustainable management systems of natural pastures for technical cadres and pastoralists

Expected outcome:

The goal of the project is to enhance food security, increase incomes, develop resilience to shocks and improve overall wellbeing of poor rural households.

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9 PEOPLE INTERVIEWED

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Dr. Abbas Korena, the Secretary for Sudan National Strategic Plan.

Mr. Sabri, State Minister for Agriculture and Forests, Undersecretary, Ministry of Agriculture and forests.

Mr. Al Amin Hassan Al Amin, Director General for Foreign Relations, Ministry of Agriculture and Forests.

Ms. Magda Elhadi Ahmed Yousif, National Research Council.

Dr. Abubakr Ibrahim, Director General, Agricultural Research Corporation.

Mr. Hashim Hassan Al Taib, Director, Agricultural Irrigation Unit, Ministry of Agriculture and Forests.

Al-Toum Osman, Resource person. Ministry of Water Resources, Electricity and Irrigation.

10 ANNEXES

Annex 1: Summary of Challenges and Opportunities

Challenge	Description	Opportunity
Geo-political and socio-economic structures		
Water resources security	<p>Dependence on external sources of water (River Nile, Gash and Baraka), energy (imported electricity and diesel)</p> <p>Establishment of the WEF Nexus basin/aquifer organizations/authorities is at early stage</p> <p>Aging water management institutions though with clear mandate and capacity to implement WEF Nexus plans.</p>	<p>Activating trans-boundary agreements and coordination bound with legal measures, joint development projects, and trade protocols</p> <p>Integrated planning of new hydropower generation dams with current and future changes in energy producing systems in neighboring countries, especially Ethiopia</p> <p>Promoting economic cooperation between Eastern Nile Basin countries and establishing electricity connectivity projects.</p>
Energy security	<p>Resolving conflicts over land ownership (expansion of petroleum oilfields over pastures).</p> <p>Irregular supply</p> <p>High cost of maintenance of diesel pumps</p> <p>Lack of access to cheap energy in rural areas</p>	<p>Expanding the national electricity network, rehabilitating hydroelectric generating stations and strengthening their operational capacity</p> <p>Generating electrical energy through renewable energy resources such as solar energy, wind, hydropower and artesian heat</p> <p>Dealing with the present grid losses and enhancing administrative and commercial capacity</p>
Agriculture and Food security	<p>Slow progress in agricultural productivity and production due to fragmented management and inefficient use of WEF resources</p> <p>Incidents of food deficits</p> <p>Dependence on variable, erratic rainfall and short rainy season</p> <p>Vulnerability to climate change, dry spells that last 20-30 days hampering plant germination and normal growth, floods that submerge land causing damage to plants</p> <p>Low food crop productivity and weak competitiveness due to high cost of production caused by inefficiencies in water, energy utilization and food production management system</p>	<p>Increasing water use efficiency and reducing overall water demand and, accordingly, energy demand.</p> <p>Increase application of appropriate technology (good seeds, resistant crop varieties, fertilizers, animal-driven implements and supplementary irrigation)</p> <p>Enhance private-sector agricultural water and energy supply services and providing training opportunities for private companies and farmers cooperatives in this area</p> <p>Improve water harvesting systems for supplementary irrigation for small producers</p> <p>Apply Zero tillage, conservative agriculture</p> <p>Apply agro-ecology system: agro-forestry and livestock production approach</p>

	<p>Absence of crop-water requirements information and application methods</p> <p>Water loss from open channels and canals</p> <p>Unorganized distribution of irrigation water quota among farmers</p> <p>High cost of cleaning silt in large irrigation canals</p> <p>Fragmented water harvesting institutions and programs (especially for small producers)</p> <p>Poor coordination resulting in ineffective policy implementation</p>	
Institutional		
Administrative	<p>Complex, sector-based structures (overlapping and non-defined limits of authorities)</p> <p>Absence of integration among WEF sectors and cross sectors</p> <p>Conflicts between federal and state ministries in implementing WEF programs and projects at the state and locality levels</p> <p>Overlooking communities' opinions and participation in policy-formulation process</p> <p>Undefined roles at state level dealing with WEF interstate resources (states sharing common water resources)</p>	<p>Institutional and policy reforms for integrated water resources management</p> <p>Reforming the legislative framework and system of subsidies in the energy sector</p> <p>Supporting and committing to initiatives to promote a Green Economy</p> <p>Mainstreaming with the Sustainable Development Strategy for 2015-2030</p> <p>Developing WEF Nexus implementation mechanism by establishing a High Council for WEF Nexus supported by the activation of the High-Water Council, Higher Council for Environment and Natural Resources (HCENR) and of National Committee on the SDGs</p>
Regulatory	<p>Sector-based and overlapping laws and regulations</p> <p>Poor enforcement of laws and regulations</p> <p>Outdated laws and regulations</p> <p>Drawbacks due to lack of a legal framework for trans-boundary cooperation</p> <p>Poor enforcement of standards and specifications rules on imported machinery and equipment using fuel</p> <p>Weakness in the application of rules and laws</p>	<p>Revise laws and regulations to remove overlap and duplications and introduce new laws that comply with internal and international changes</p> <p>Legal framework for trans-boundary cooperation is at early stage (Nubian sand stone, on Gash and Baraka and with South Sudan)</p> <p>Enforcing the application of rules and laws</p>
Planning and policy formulation and M&E	<p>Sector-based planning and policies, and their overlapping with sector dominance</p> <p>Incomplete implementation of most WEF sector plans</p> <p>Fragmented management and coordination of WEF Nexus policy and strategic planning</p> <p>Limited role of private sector in WEF Nexus development, management and use</p>	<p>Assign higher rank of pro-small-agricultural-producers' policies and programs in rainfed area</p> <p>Fully implement the Poverty Alleviation Program</p> <p>Address gender issues in WEF Nexus with relevant policies and strategies, and through budgets and capacity building</p>

	<p>Despite existence of WEF Nexus-based water policy and strategy in the country, still it is at its early stages of implementation.</p> <p>Limited community participation in policy and strategic planning and limited involvement in water resources management</p> <p>Need for orientation of private sector in WEF Nexus development, management and use</p> <p>Limited scale planning for sustainable aquifer management</p> <p>Weak checks and balances mechanism due to existing bureaucratic practice of monitoring and evaluation system (receiving regular reports with neither analysis nor interpretation)</p> <p>Poor finance for conducting proper M&E</p> <p>Inadequate baseline data and information to be used as indicators for M&E reference and follow up</p> <p>Lack of awareness about strategic objectives of the 25-Year Development plans and the SDGs</p> <p>Limited monitoring of water discharge to the River Nile system and neglecting the other seasonal streams</p> <p>Poor weather monitoring stations,</p> <p>Limited wastewater treatment,</p> <p>No water quality monitoring arrangements exist outside the Nile system</p>	<p>Support and focus on the management of the hydrological units (watersheds and aquifers) in the currently ongoing revision of the National Water Policy (MWREI and JICA). The new revised policy has to include the development of a national Integrated Water Resources Management (IWRM) Strategy.</p> <p>Optimization and rehabilitation of dam infrastructure</p> <p>Considering fish production in dam management</p> <p>Keep up-to-date management information system (MIS) on budgeting and water accounting for technical and financial planning and M&E purposes</p> <p>Strengthen the M&E systems of WEF Nexus based on strategic objectives and SDG indicators.</p>
Capacity building	<p>Inadequate management of human resources and up-scaling of skills in planning, policy making, implementation of programs, projects and activities</p> <p>Delays in undertaking decisions on credit supply, provision of inputs and services</p> <p>Low capacity at federal, state and locality levels related to WEF Nexus policies and plans</p> <p>Lack of human resources capacities (planning, policy formulation and M&E)</p> <p>Insufficient training opportunities for personnel at all levels and limited upgrading of communication skills</p> <p>Inadequate institutional capacity to enhance proficiency, especially in the area of the WEF approach - implementation of WEF Nexus institutions at national, state and other levels.</p>	<p>Building the WEF sector capacities by training personnel at all levels, enhancing work-environment, implementing structural and institutional reform and using technology to modernize information base</p> <p>Plan for regular capacity building to enhance proficiency especially in the area of WEF approach</p>

	<p>Shortage in skilled capacities for the management of WEF Nexus policies and plans</p> <p>Lack of projection capacity about climate incidents, marketing opportunities and prices, investment opportunities and selection of the right commodity or service</p> <p>Misuse of logistics result in delays of services provided on time and in place</p>	
Statistics departments in WEF sectors	<p>Fragmented and unreliable data on WEF sectors</p> <p>Limited dissemination and exchange of available data and information among partners</p> <p>Questionable data quality and limited data sharing at both the country and trans-boundary levels</p> <p>Lack of a database on energy-sector supply and demand and lack of exchange of information between the federal and state levels</p> <p>Limited knowledge and information sharing regarding the existing early warning system and its signals</p>	<p>Strengthen integrated data collection and information</p> <p>Develop effective mechanism for maximum sharing among users in the WEF sector departments</p> <p>Building database on energy-sector supply and demand and encouraging exchange of information at federal and state levels.</p>
Economical		
Macroeconomics	<p>High cost of inputs, transportation and high food prices due to instability of economic policies (dual exchange rate, deficit financing, removal of subsidies for energy and bread-wheat and sugar and high import tariffs)</p> <p>Inadequate use of economic tools to enhance water-use efficiency (WUE).</p>	<p>Apply economic tools to WEF sector tradeoff activities</p> <p>Reform macroeconomic policies using market incentives and removing of taxes</p> <p>Optimize the financial and technical resource allocations based on comparative advantage of sector value-chain systems to increase resource use efficiency for producing competitive food crops and livestock products in domestic and export markets</p>
Finance and Investment	<p>Inadequate but selective finance and investment on specific WEF sectors at the expense of others creates barriers to integrated WEF program</p> <p>Reduction in crop areas cultivated by corporations due to inability to finance cleaning and maintenance of irrigation canals</p> <p>Severe water-borne pests and diseases (malaria and bilharzia)</p> <p>Inadequate finance for education, training and research</p>	<p>Encouraging private investment</p> <p>Reorganize the financing program giving higher priority to WEF sector programs and projects</p> <p>Mobilize PPP financial resources and encourage farm-contract mechanism between private sector and small producers, especially the poor and women in the dryland areas</p> <p>Increase the Capital of the Agricultural Bank and facilitate supplies of credit to small producers</p> <p>Opening the markets for electricity utilities, generation, distribution and sales to private investment – involving them in marketing and processing of water equipment and tools</p>

		Organize and integrate UN programs and other internationally funded projects into WEF sectors (including community development and adaptive projects)
Infrastructure	Poor WEF infrastructure to support agricultural sector growth and strengthening of value chains	Allocate more government finance to construct main and rural roads, warehouses and silos and telecommunication systems
Energy- (electricity and fuel and biomass)	Limited access to modern energy and heavy reliance on traditional biomass energy High dependence on wood fuel and charcoal for cooking Electricity access deficit	
R&D and Technology transfer		
Research & Development	Discipline-oriented research Inappropriate and inadequate R&D due to poor finance and human resources Fragmented application of WEF research Limited models and approaches to technology transfer Slow adoption of new innovation among recipients (government staff and target communities and farmers)	Develop R&D vision for integrated WEF sectors – linked to the development strategies, plans, policies and programs of each sector Undertake joint research and studies on water resource development and legal rights allocations and strengthen applied research in areas related to water harvesting
Technology transfer	Weak transfer of technology due to limited finances and poorly staffed institutions	Provide financing to improve institutional capacity to expand transfer of successful technologies
Adoption	Limited coordination and adoption of the WEF Nexus plans and strategies described in the midterm constitution, the 25-Year Development Strategy (2007-2031), NAP, NAPA and NBSAP and other national development strategies and plans Low adoption of improved technology and poor management Poor marketing skills due to culture and poorly financed programs	Improve awareness about availability and uses of appropriate technological packages Adopt methods for changing culture and social attitudes towards WEF Nexus approach Apply demonstration farms to convince farmers and related government staff, private sector and communities to expedite adoption of WEF Nexus approach
Environment and climate change		
Natural resources and climate change	Biased land-use allocation to expansion of agriculture, mines (gold) and oil fields at the expense of watersheds, forests and rangelands and pastures and biodiversity Degraded biodiversity due to expansion of agriculture, mining and petroleum drilling activities over forests and range and pasture land Unsettled land tenure	Activate the national associations affiliated with Paris Climate Change agreement and SDG implementation: Activate the Green Wall and the Green Economy Initiatives Expand the National Committee for SDGs to include WEF Nexus issues and aspects Risk evasion and management and risk insurance programs and measures and mechanisms

	<p>Land degradation and desertification</p> <p>Increasing temperature and rainfall isohyets moving southwards</p> <p>Frequent exposure to droughts and floods with hard hit crop seasons</p> <p>Non-functioning of some federal and state disaster risk management (DRM) authorities and non-functional flood early warning system</p>	
Drought and desertification	<p>Cyclical droughts and floods affecting water, energy and food production (hitting crop production and resulting in the loss of the agricultural seasons)</p> <p>Desert encroachment over arable land</p> <p>Poor enforcement of natural resources protection laws</p>	<p>Risk management programs</p> <p>Risk evasion activities</p> <p>Crop and livestock insurance</p> <p>Solar pumps insurance</p> <p>Enforcement of forest conservation and protection laws</p> <p>Enforcement of Environment Protection Act 2002</p>
Degradation of forests	<p>Deforestation due to extensive cutting of forest trees for biomass energy and income generation</p> <p>Forest degradation due to overgrazing of shrubs and tree branches</p> <p>High dependence of communities and IDPs of cutting forests for firewood for home cooking and for income generation</p> <p>Extensive charcoal making for use in urban areas</p>	
Overgrazing of rangelands and pasture	<p>Increasing number rather than improving quality of livestock resulting in overgrazing of range and pasture and attacks on crops</p> <p>Overgrazing of rangelands and pastures with loss of palatable plants and domination of alien grasses</p> <p>Limited movement of animals due to conflicts and closure of stock routes</p>	

Annex 2: Nexus Ranking

Annex Table 1: Assessment of projects during the validation workshop (February 12, 2019)

No.	Project Title	Ranking* (X means deletion)				Total
1	WEF Nexus Dialogue and Pilot	1	3	4 (unified data base)	2	10
2	Gezira Dialogue and Pilot	2 (focus on capacity building, credit & insurance)				5
3	Nubian Sandstone Aquifer Monitoring & Dialogue	0		4	1	5
4	Merowe Livelihood Improvement Project	4	2			6
5a	Water Harvesting Blue Nile	3 (Energy, Food and livestock)			4	12
5b	Water Harvesting White Nile	3	5		4	12
5c	Regional Water Harvesting	3	5	2	4	14
6	Biofuel-Sweet Sorghum	X	X			X
7	Reservoir Fisheries	X	3			--
8	Solar Home and irrigation Darfur, etc.	5	2	3	2	12
N1	Integrated land management project (ILM) Alrawakeeb R.S.					
N2	Mobile Solar energy-based irrigation project				4	4
N3	Use of Remote Sensing Techniques for the estimation of WP of wheat in White Nile State				4	4
N4	Small-Scale water harvesting				3	3
N5	Climate Change Adaptation in Remote Areas		10			10
N6	Processing of sweet sorghum in rainfed areas to produce brown sugar			4		4

N7	Water harvesting for Nomads (settlements) & returnees in Darfur and Kordofan			3		3
N8	Promotion of new technologies for WH addressing small-scale producers					

Notes: *The higher the number, the better the ranking; X denotes proposed removal of the project; the top ranked project by group as well as those proposed for elimination are indicated in color red.

Annex 3: Additional information on newly proposed projects:

N1: Integrated Land Management (ILM):

The project would include a focus on crop production, animal production, fish production, food processing and farmer training, including training in organic farming. The energy source would be solar for pumping irrigation water. The project would also focus on addressing adverse impacts from climate change.

Implementers/Funding: NCR/MOMSR and private sector

Budget: USD 200,000 (ARID)

N2: Mobile Solar energy-based irrigation project (G1)

Multiple uses by farmers, low-cost system,

Implementers: MOWRIE & MOAF

N3: Use of Remote Sensing Techniques for the estimation of WP of wheat in White Nile State:

This tool enables the estimation of water productivity at a regional scale, allowing for the identification and reduction of gaps in water productivity.

Implementers: AOAD and research institutions

N4: Small-scale water harvesting lined pit and solar supply system

Such a system would support rainfed farmers

Implementer: MOAF & AOAD

N5: Climate-change adaptation in remote areas (promoting the Jubarik Model)

This is an intervention for women's empowerment. It includes the following Nexus elements: Water management (family storage tank), solar energy (for water pumping), food security (growing of vegetables, fattening of small ruminants and environmental protection), the project is VC style.

Implementation: Ministry of Agriculture, Ministry of Environment, University of Khartoum, NCR

Budget: USD 300,000

Biofuel Pilot Project (North Kordofan State) (rejected during February 12, 2019 Validation workshop)

Background:

To support the implementation of the Ministry of Oil, Gas and Minerals (MOGM) roadmap for producing biofuels during 2020 – 2035.

Objectives:

Implement a pilot biofuel feedstock project in Sudan focusing on sweet sorghum

Establish cottage industry for producing biofuel by small producers in North Kordofan State

Budget: USD 150,000 for crop production and cottage processing program

Potential Project Implementers: MWREI, MOAF, MAR&F, MOFEP, Ministry of Industry and Foreign trade (Moi&FT), ICRISAT, State Ministries of agriculture and animal resources and physical planning, FAO/AgWm, IFAD,

Linkages with other projects: All projects concerning biofuel production, clean energy

Project Category: Energy improvement project

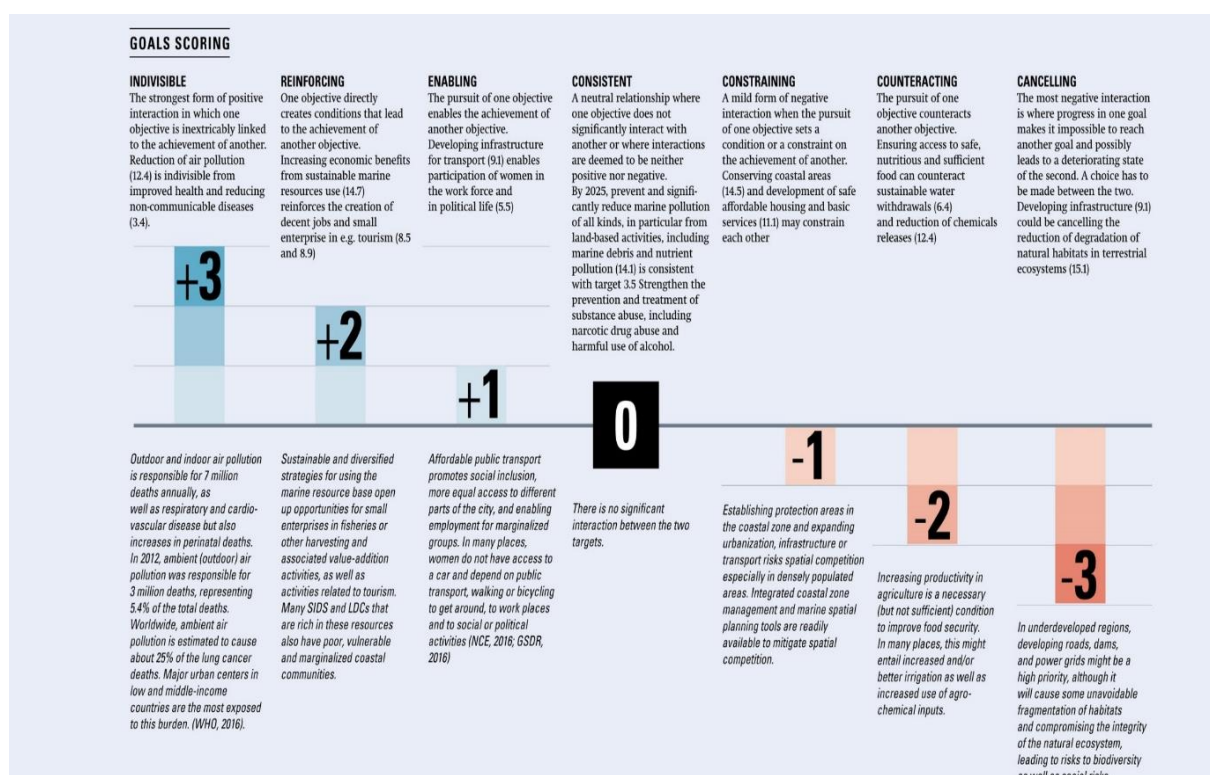
Contribution to the Strategic Plan: Provide access to biofuels, increase household revenue, enhance food security

SDG Target 2 and other WEF Nexus targets

Annex 4: ICSU Framework

ICSU (2016)⁶ developed a 7-point scoring framework. This allows us to identify the size and strength of inter-linkages between activities or of activities with specific goals. A scoring of +3 signifies “indivisible” (i.e., that a goal, such as water security, cannot be achieved without investing in this specific activity). Other rankings include strong or weak positive association (+2 or +1, respectively) with a specific Nexus goal, neutral association (0) and negative associations, weak or strong (-1 or -2, respectively). If the activity would make it impossible to achieve a Nexus objective, the ranking would be -3.

Annex Figure 1: Interaction Framework of ICSU (based on ICSU 2016)



⁶ ICSU (International Council for Science). 2016. Working Paper. A draft framework for understanding SDG interactions. Paris: ICSU.