GEF-08 Project:

Building Climate Resilience of Vulnerable Groups in Rural and Urban Areas of Yemen

Inception and Baseline Report







Ministry of Water and Environment
Climate Change Unit

WSS Project
مشروع المياه والصرف الصحي للمدن الحضرية

September 2025
Aden, Yemen

UNDP

List of Acronyms

BCM	Billion Cubic Meters
CARE	Cooperative for Assistance and Relief Everywhere
CCDR	Country Climate and Development Report
CCU	Climate Change Unit
EPA	Environmental Protection Authority
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GEF	Global Environment Facility
IIP	Irrigation Improvement Project
IOM	International Organization for Migration
IWRM	Integrated Water Resources Management
LDCF	Least Developed Countries Fund
MAR	Managed Aquifer Recharge
MCM/year	Million Cubic Meters per Year
MoAIF	Ministry of Agriculture and Irrigation & Fisheries
MWE	Ministry of Water and Environment
NIP	National Irrigation Program
NWRA	National Water Resources Authority
RFI	Requests for Information
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UN-Habitat	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
UNEP	United Nations Environment Programme
WB	World Bank
WHO	World Health Organization
WRAY	Water Resources Assessment for Yemen (assumed)
WUAs	Water User Associations
BAP	Biodiversity Action Plan
CSA	climate-smart agriculture
CSI	Climate Science Investigations
EbA	Ecosystem-based Adaptation
ESMF	Environmental and Social Management Framework
FGDs	Focus Group Discussions
FMNR	Farmer Managed Natural Regeneration
FSLA	Food Security and Livelihoods Assessment
HHs	Households
IE	International Expert
IGAs	Income Generating Activities
IPM	Integrated pest management
IRG	International Recognized Government
IWM	Integrated weed management
KIIs	Key Informant Interviews
MAIF	Ministry of Agriculture, Irrigation and Fisheries

MOPIC	Ministry of planning and international cooperation
NE	National Expert
NGO	Non-Government Organization

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EXECUTIVE SUMMARY

Yemen stands at a critical crossroads where conflict, fragility, and climate change converge to create one of the world's most severe humanitarian and environmental crises. More than two decades of conflict have weakened institutions and infrastructure, while climate hazards—droughts, floods, salinity intrusion, and heatwaves—grow more severe each year. These shocks dismantle agriculture, degrade ecosystems, overwhelm services, and drive displacement, with nearly half of the population directly exposed to climate risks and one quarter facing food insecurity. Without urgent adaptation, Yemen's GDP could decline by nearly four percent by 2040, while health costs may rise by over five billion dollars by 2050.

This crisis transcends individual sectors and requires an integrated policy response. Water, agriculture, energy, health, and education are not standalone domains but interdependent systems whose vulnerabilities reinforce one another. Water scarcity directly reduces food production and increases health risks, while energy poverty limits the operation of water supply networks, wastewater treatment, and agro-processing. Degraded ecosystems and collapsing public services accelerate displacement, undermine social stability, and erode development gains. International evidence shows that fragmented sectoral responses often fail in fragile contexts, while nexus-based and area-focused approaches—linking water, energy, food, and ecosystems—deliver higher returns on investment, strengthen adaptive capacity, and reduce conflict risks. For Yemen, this means embedding integrated planning into local and national policy frameworks, aligning resource allocation with cross-sectoral priorities, and ensuring donor financing supports coherent territorial interventions rather than isolated projects. Only through such a coordinated, evidence-driven approach can resilience be built on a scale and sustained over time.

The impacts are felt most acutely by vulnerable groups. These include smallholder farmers, pastoralists, and fishers whose livelihoods depend on fragile resources; women and girls who shoulder the burden of securing food, water, and household energy; children whose health and education are disrupted by unsafe schools and extreme heat; youth with limited opportunities; and internally displaced people living in precarious shelters with little access to services. For these groups, climate shocks mean failed harvests, lost income, unsafe water, disrupted education, and rising health risks. The five targeted governorates under the GEF-08 Project—Shabwah (Bayhan, Nisab, Rudhom, Markha Al-Sufla), Abyan (Lawder, Ahwar, Al-Mahfd, Sarar), Aden, Al-Hudaydah, and Hadramout (Al-Mukalla)—represent areas where climate impacts on these groups are most severe.

Shabwah, situated between the central highlands and the Gulf of Aden coast is highly vulnerable to recurrent floods, prolonged droughts, and advancing salinity that together undermine its agricultural and pastoral economy. In Bayhan, repeated floods destroy spate irrigation canals and strip fertile soils, weakening both crop production and groundwater recharge. Nisab endures persistent drought and saline intrusion that contaminate shallow wells, disrupt farming, and reduce livestock and honey production, forcing reliance on costly water trucking. Markha Al-Sufla is highly exposed to catastrophic floods from Wadi Khuwrah and Wadi Markha, which damage irrigation systems, wash away cropland, and threaten nearby villages. Rudhom, a coastal district, is doubly exposed to flash floods and cyclones that damage date groves, fisheries, and transport routes, while sea-level rise and saline intrusion jeopardize both communities and critical facilities such as Balhaf LNG and Nashima Oil Terminal.

Abyan's vulnerability stems from severe hydro-climatic variability—intensifying droughts punctuated by destructive floods and coastal hazards—that erode its historic role as one of Yemen's breadbaskets. Lawder faces growing drought that dries wells, reduces soil moisture, and cuts yields of cereals and vegetables, depressing household incomes. Ahwar's fertile delta is repeatedly devastated by flash floods and cyclones, which erode soils, destroy irrigation works, and salinize coastal farmlands, leaving agriculture and fisheries unstable. Al-Mahfad suffers from persistent drought that shrinks rangelands and weakens livestock production, with occasional floods compounding soil erosion. Sarar experiences some of the harshest impacts of water scarcity and land degradation, as collapsed terraces accelerate erosion and runoff; coffee production has fallen by more than 80 percent, while the scarcity of water has driven prices to extremely high levels, forcing households to depend on costly trucking.

Aden's vulnerability is dominated by structural water scarcity compounded by salinity, flooding, and extreme heat. The city faces an annual water deficit exceeding 80 million cubic meters, while groundwater salinity of 5,000–8,000 mg/L renders much of the resource unusable. Recurrent floods and longer, hotter heatwaves make homes, schools, and clinics uninhabitable. Informal settlements and IDP camps in low-lying areas are especially exposed to health and livelihood risks due to inadequate drainage, poor infrastructure, and lack of safe cooling.

Al-Hudaydah. Al-Hudaydah on the Red Sea coast exhibits compounded coastal vulnerability where floods, salinity, heat, and weak infrastructure converge on fragile services and livelihoods. Flash floods repeatedly destroy homes, farmland, and roads; more than 60 percent of shallow wells are now saline; and inadequate sanitation systems contaminate aquifers, driving recurrent cholera and diarrhea outbreaks. Intensifying heatwaves, combined with high humidity, create oppressive and hazardous conditions that reduce safe working hours for farmers and fishers, cut productivity, and heighten health risks. Schools are equally affected, with classrooms becoming unsafe during extreme heat, leading to absenteeism and frequent interruptions in education, particularly for girls. For more than 45,000 IDPs living in fragile shelters, the combination of heat, floods, and unsafe water leaves families without reliable refuge.

Hadramout, and especially its capital Al-Mukalla, faces overlapping inland and coastal risks that disrupt urban systems and services. Flash floods from Wadis regularly inundate the city, damaging housing, markets, and transport infrastructure. Along the Arabian Sea coast, cyclones intensify these impacts by destroying fishing infrastructure, salinizing soils, and disrupting port operations. Escalating heatwaves compound the crisis, with schools and clinics frequently forced to close due to unsafe conditions, while unreliable electricity leaves children and patients especially vulnerable.

Water scarcity is Yemen's most urgent crisis. Renewable resources of 2.5 billion cubic meters annually fall far short of withdrawals exceeding five billion, causing groundwater declines of up to six meters per year. Salinity intrusion renders wells in Rudhom, Nisab, Aden, and Al-Hudaydah unfit for use. Wastewater reuse has become a critical but risky coping strategy: in Bayhan, Nisab, and Lawder, untreated wastewater is increasingly used for irrigation as aquifers dry. While this provides temporary relief, it contaminates wells and soils, accelerating salinization and undermining ecosystems. Drought makes this situation worse, as declining groundwater volumes mean contaminants are less diluted, increasing health risks and accelerating degradation. In Al-Hudaydah, fragile sanitation systems exacerbate this problem, polluting aquifers and fueling outbreaks of waterborne disease.

Agriculture, central to livelihoods in Shabwah and Abyan, is being dismantled by prolonged droughts, fodder shortages, and declining soil fertility. Floods and cyclones repeatedly destroy irrigation infrastructure, wash away fertile soil, and damage fisheries and storage systems. Upland terrace collapse accelerates runoff and erosion, while coastal fisheries face warming seas and rising post-harvest losses. Ecosystem degradation, including uncontrolled grazing, invasive mesquite, and deforestation, further weakens resilience and income sources.

At the same time, the collapse of Yemen's electricity grid has left only 15 percent of households connected, while diesel dependence drains over one billion dollars annually. Energy poverty undermines water pumping, desalination, wastewater treatment, agro-processing, cold storage, and fisheries preservation. Schools and clinics lack power, water, and cooling, leaving children and patients exposed to unsafe conditions. Without reliable energy, Yemen's adaptive capacity collapses further: communities cannot pump or desalinate water during droughts, cannot power cooling systems during heatwaves, and cannot protect crops and fish from spoilage during floods and cyclones.

The project "Building the Climate Resilience of Vulnerable Groups in Rural and Urban Yemen" will deliver integrated interventions designed around the nexus of water, agriculture, energy, and livelihoods. In the water sector, the project will rehabilitate wastewater treatment plants and decentralized reuse systems, expand rainwater harvesting and recharge structures, deploy solar-powered desalination units in saline hotspots, and implement Integrated Water Resources Management (IWRM) plans in selected districts. In agriculture, it will introduce climate-smart technologies such as drip irrigation, mulching, protective tunnels, and nurseries, alongside the rehabilitation of spate irrigation and upland terraces to conserve water and reduce erosion. Ecosystem-based adaptation measures will include reforestation of Sidr and date palms, rangeland rehabilitation, and grazing control, supported by investments in value chains for sesame, dates, lemons, honey, and fisheries through solar-powered processing and cold storage. In the energy sector, renewable solutions will be scaled up, with Green Schools integrating solar PV, shading, and water systems to provide safe learning environments while serving as resilience hubs for communities. Solar-powered productive-use systems will drive water pumping, desalination, agro-processing, and fisheries, directly linking energy to food and water security. Institutions will be supported to develop standards, policies, and financing mechanisms to sustain decentralized renewable energy markets.

To ensure sustainability and replication, the project will invest in capacity building and planning. Local authorities, water user associations, and community groups will be trained in operation, maintenance, and climate-resilient planning. Knowledge products and training manuals will embed adaptation practices into schools and community systems. The project will prepare district-level integrated water and land-use plans, investment studies for renewable energy scale-up, and replication roadmaps to guide future interventions, supported by a robust monitoring and evaluation system.

This project adopts a nexus-based strategy in which renewable energy sustains water and livelihoods, water secures agriculture and ecosystems, and resilient livelihoods reduce poverty, displacement, and conflict. Schools anchor resilience by safeguarding children and serving as community hubs. The expected impacts include improved water security for hundreds of thousands of households, crop yields increased by up to 30 percent, revitalized value chains, reduced diesel use and emissions, and climate-resilient schools. Women, youth, and displaced populations will be empowered through participation in value chains, training, and energy-enabled livelihoods.

الملخص التنفيذي

تقف اليمن عند مفترق طرق حاسم حيث تتقاطع النزاعات والهشاشة مع تغيّر المناخ لتشكّل واحدة من أشد الأزمات الإنسانية والبيئية في العالم. فقد أدّت أكثر من عقدين من الصراع إلى إضعاف المؤسسات والبنية التحتية، بينما تتزايد حدّة المخاطر المناخية ــ من جفاف وفيضانات وتملّح وارتفاع درجات الحرارة ــ عاماً بعد عام. هذه الصدمات تقوّض الزراعة، وتسرّع من تدهور النظم البيئية، وتنهك الخدمات الأساسية، وتدفع بموجات نزوح واسعة، حيث يتعرّض ما يقارب نصف السكان مباشرة للمخاطر المناخية، فيما يعاني ربعهم من انعدام الأمن الغذائي. ومن دون تكيّف عاجل، قد ينخفض الناتج المحلي الإجمالي لليمن بنحو 4% بحلول عام 2040، بينما قد ترتفع التكاليف الصحية بأكثر من 5 مليارات دولار بحلول عام 2050.

هذه الأزمة تتجاوز القطاعات الفردية وتتطلب استجابة متكاملة للسياسات. فالمياه والزراعة والطاقة والصحة والتعليم ليست مجالات مستقلة، بل أنظمة مترابطة تتعزز هشاشتها بعضها ببعض. فشح المياه يقلل من الإنتاج الغذائي ويزيد من المخاطر الصحية، بينما يحد فقر الطاقة من تشغيل شبكات إمداد المياه ومحطات معالجة الصرف والتحويل الزراعي. كما يسرّع تدهور النظم البيئية وانهيار الخدمات العامة من النزوح، ويقوّض الاستقرار الاجتماعي، ويقضي على مكتسبات التنمية. وتظهر الأدلة الدولية أن الاستجابات القطاعية المجزأة غالباً ما تفشل في البيئات الهشّة، بينما تؤدي المقاربات المترابطة والمكانية ــ التي تربط بين المياه والطاقة والغذاء والنظم البيئية ــ إلى عوائد استثمارية أعلى، وتعزيز القدرة على التكيّف، وتقليل مخاطر النزاعات. وفي اليمن، يعني ذلك دمج التخطيط المتكامل في الأطر المحلية والوطنية، ومواءمة تخصيص الموارد مع الأولويات المشتركة بين القطاعات، وضمان أن يوجّه تمويل المانحين إلى تدخلات متماسكة على مستوى الأقاليم بدلاً من مشروعات مجزأة. ولا يمكن بناء الصمود على نطاق واسع واستدامته إلا من خلال نهج منسق قائم على الأدلة.

وتقع التأثيرات الأشد على الفئات الأكثر هشاشة: المزارعون أصحاب الحيازات الصغيرة، والرعاة، والصيادون الذين تعتمد سبل عيشهم على موارد هشة؛ النساء والفتيات اللواتي يتحملن عبء تأمين الغذاء والمياه والطاقة المنزلية؛ الأطفال الذين تتأثر صحتهم وتعليمهم بفعل المدارس غير الآمنة وموجات الحر؛ الشباب الذين يواجهون قلة الفرص؛ والنازحون داخلياً الذين يعيشون في ملاجئ متدهورة تفتقر إلى الخدمات الأساسية. وبالنسبة لهذه الفئات، تعني الصدمات المناخية فشل المحاصيل، وفقدان الدخل، وتدهور المياه، وتعطل التعليم، وتفاقم المخاطر الصحية .المحافظات الخمس المستهدفة ضمن مشروع GEF-08 ــ شبوة، أبين، عدن، الحديدة، وحضرموت (المكلا) ــ تمثل أكثر المناطق تضرراً بالمخاطر المناخية على هذه الفئات.

تُعد شبوة شديدة الهشاشة أمام مزيج من الفيضانات المتكررة والجفاف المطوّل والتملّح المتزايد، ما يقوّض اقتصادها الزراعي والرعوي. ففي بيحان، تتسبب الفيضانات المتكررة في تدمير قنوات الري السيحي وتجريف التربة الخصبة، مما يضعف الإنتاج الزراعي وإعادة تغذية المياه الجوفية. أما نصاب، فتعاني من الجفاف الطويل وتداخل الملوحة الذي يلوث الآبار الضحلة ويعطل الزراعة ويقلل من إنتاج الثروة الحيوانية والعسل، مما يجبر السكان على الاعتماد على صهاريج المياه المكلفة. وفي مرخة السفلى، تتعرض القرى المجاورة لفيضانات كارثية من واديي خوّرة ومرخة تجرف التربة وتدمر شبكات الري والأراضي الزراعية. وعلى الساحل، تواجه رضوم فيضانات مفاجئة وأعاصير تضر ببساتين النخيل والمصايد والبنية التحتية للنقل، بينما يشكل ارتفاع مستوى البحر والتملّح خطراً على المجتمعات والمنشآت الحيوية مثل منشأة بلحاف للغاز ومحطة النشيمة النفطية.

تنبع هشاشة أبين من التقلّبات الهيدرو-مناخية الحادة ــ جفاف متزايد تقطعه فيضانات مدمرة ومخاطر ساحلية ــ مما يقوّض دورها التاريخي كسلة غذاء لليمن. ففي لودر، يجفف الجفاف الآبار ويقلل رطوبة التربة ويخفض إنتاج الحبوب والخضروات، مما يضغط على دخول الأسر. أما أحور، فتعاني دلتاها الخصبة من فيضانات متكررة وأعاصير تجرف التربة وتدمر منشآت الري وتملّح الأراضي الساحلية، مما يجعل الزراعة والمصايد غير مستقرة. وتتعرض المحفد لجفاف دائم يقلّص المراعي ويضعف إنتاج الماشية، مع فيضانات عرضية تزيد من تآكل التربة. بينما تواجه سرار بعضاً من أشد الآثار، حيث يؤدي انهيار المدرجات إلى تسريع الجريان وفقدان التربة، وانخفض إنتاج البن بأكثر من 80%، كما ارتفعت أسعار المياه إلى مستويات باهظة أجبرت الأسر على الاعتماد على صهاريج المياه المكلفة.

تتجلى هشاشة عدن في شح مائي هيكلي يتفاقم بفعل التملّح والفيضانات وارتفاع الحرارة. فالمدينة تواجه عجزاً مائياً سنوياً يتجاوز 80 مليون م³، بينما تصل ملوحة المياه الجوفية إلى 5,000–8,000ملغ/لتر، مما يجعل معظمها غير صالح للاستخدام. وتتكرر الفيضانات وموجات الحر الطويلة والحادة، مما يجعل المنازل والمدارس والعيادات غير صالحة للسكن. كما أن المستوطنات العشوائية ومخيمات

النازحين في المناطق المنخفضة معرضة بشكل خاص لمخاطر صحية ومعيشية نتيجة ضعف الصرف وسوء البنية التحتية وغياب وسائل التبريد الآمنة.

تُظهر الحديدة على ساحل البحر الأحمر هشاشة ساحلية مركّبة حيث تتقاطع الفيضانات والتملّح وموجات الحر وضعف البنية التحتية على الخدمات وسبل العيش الهشة. فالفيضانات المفاجئة تدمر المنازل والأراضي الزراعية والطرق بشكل متكرر، وأكثر من 60% من الآبار الضحلة أصبحت مالحة، في حين أن أنظمة الصرف الصحي غير الكافية تلوث الأحواض الجوفية مسببة تفشي متكرر للكوليرا والإسهالات. إن اشتداد موجات الحر مقترنة بالرطوبة العالية يخلق ظروفاً خانقة وخطيرة تقلل من ساعات العمل الآمنة للمزارعين والصيادين، وتخفض الإنتاجية، وتزيد من المخاطر الصحية. كما تتأثر المدارس بشكل مباشر، حيث تصبح الفصول الدراسية غير آمنة أثناء موجات الحر الشديدة، مما يؤدي إلى الغياب والانقطاعات المتكررة في العملية التعليمية، خصوصاً للفتيات. وبالنسبة لأكثر من 45,000 نازح يعيشون في ملاجئ هشة، فإن مزيج الحرارة والفيضانات والمياه غير الآمنة يترك الأسر من دون ملاذ آمن يعتمد عليه.

تواجه حضرموت، وخاصة عاصمتها المكلا، مخاطر داخلية وساحلية متداخلة تعطل الأنظمة الحضرية والخدمات الأساسية. ففيضانات الأودية تغمر المدينة بانتظام، مدمرة المساكن والأسواق والبنية التحتية للنقل. وعلى طول ساحل بحر العرب، تزيد الأعاصير من هذه الآثار من خلال تدمير مرافق الصيد وتملّح التربة وتعطيل العمليات الميناائية. وتفاقم موجات الحر المتزايدة الأزمة، حيث تُجبر المدارس والعيادات على الإغلاق المتكرر بسبب الظروف غير الآمنة، فيما يترك غياب الكهرباء الموثوقة الأطفال والمرضى في أوضاع بالغة الخطورة.

يُعد شح المياه الأزمة الأكثر إلحاحاً في المحافظات المستهدفة. فالموارد المتجددة البالغة 2.5 مليار م³ سنوياً لا تغطي السحوبات التي تتجاوز 5 مليارات، مما يؤدي إلى انخفاض منسوب المياه الجوفية بما يصل إلى 6 أمتار سنوياً. التملّح جعل الآبار في رضوم ونصاب وعدن والحديدة غير صالحة للاستخدام. ومع جفاف الأحواض، أصبح إعادة استخدام مياه الصرف استراتيجية تكيّف حرجة ولكن محفوفة بالمخاطر. ففي بيحان ونصاب ولودر، يزداد اعتماد المزارعين والأسر على مياه الصرف غير المعالجة للري مع جفاف الآبار، وهو ما يوفّر حلاً مؤقتاً لكنه يلوث الآبار والتربة ويعجّل التملّح ويقوّض النظم البيئية. ويجعل الجفاف هذا الوضع أكثر خطورة، حيث يقل حجم المياه الجوفية وبالتالي تقل قدرتها على تخفيف الملوثات، مما يضاعف المخاطر الصحية والتدهور البيئي. أما في الحديدة، فإن هشاشة أنظمة الصرف الصحي تساهم في تفاقم المشكلة، ملوثة الأحواض ومغذية تفشي الأمراض المنقولة بالمياه.

تشكل الزراعة، التي تبقى مركزية لسبل العيش في شبوة وأبين، قطاعاً متفككاً بفعل الجفاف الطويل ونقص الأعلاف وتدهور خصوبة التربة. فالفيضانات والأعاصير تدمر البنية التحتية للري، وتجرف التربة الخصبة، وتضر بالمصايد ومنشآت التخزين. وفي المرتفعات، يسرع انهيار المدرجات من الجريان وتآكل التربة، بينما تواجه المصايد الساحلية بحاراً أكثر دفئاً وخسائر بعد الحصاد متزايدة. كما يفاقم تدهور النظم البيئية، بما في ذلك الرعي غير المنضبط وانتشار شجرة المسكيت وإزالة الغابات، من ضعف القدرة على الصمود وفقدان مصادر الدخل.

انهار نظام الكهرباء المركزي في اليمن، ولم يتبق سوى 15% من الأسر متصلة بالشبكة، فيما يستنزف الاعتماد على الديزل أكثر من مليار دولار سنوياً. ويقوّض فقر الطاقة تشغيل الضخ والتحلية ومعالجة الصرف والتصنيع الزراعي والتخزين البارد وحفظ الأسماك. كما تفتقر المدارس والعيادات إلى الطاقة والمياه والتبريد، مما يترك الأطفال والمرضى في ظروف غير آمنة. ومن دون طاقة موثوقة، تنهار قدرة التكيّف أكثر: لا يمكن للمجتمعات ضخ أو تحلية المياه أثناء الجفاف، ولا تشغيل أنظمة التبريد أثناء موجات الحر، ولا حماية المحاصيل والأسماك من التلف أثناء الفيضانات والأعاصير.

سيقدّم مشروع **"بناء القدرة على الصمود المناخي للفئات الهشة في المناطق الريفية والحضرية في اليمن "**حزمة متكاملة من التدخلات مصممة حول ترابط المياه والزراعة والطاقة وسبل العيش:

- في **قطاع المياه** :إعادة تأهيل محطات المعالجة وأنظمة إعادة الاستخدام اللامركزية، توسيع حصاد مياه الأمطار وهياكل التغذية الجوفية، وخزن المياه، نشر وحدات التحلية بالطاقة الشمسية في مناطق التملّح، وتنفيذ خطط للإدارة المتكاملة للموارد المائية (IWRM)في مديريات مختارة.

- في **الزراعة** :إدخال تقنيات ذكية مناخياً مثل الري بالتنقيط والتغطية والأنفاق والمشاتل، إلى جانب إعادة تأهيل منشآت الري السيلي والمدرجات. وتشمل التدابير البيئية إعادة تشجير السدر والنخيل، وتأهيل المراعي، وتنظيم الرعي. كما ستُعزَّز سلاسل القيمة للسمسم والتمور والليمون والعسل والمصايد عبر المعالجة والتخزين البارد بالطاقة الشمسية. وسيُستفاد من شجرة المسكيت الغازية في إنتاج الفحم أو الأعلاف كوسيلة لاستعادة الأراضي وتوليد الدخل.

- ستتوسع الحلول المتجددة، مع مدارس خضراء تدمج الطاقة الشمسية والتظليل والتشجير وأنظمة المياه لتوفير بيئة تعليمية آمنة، بينما تخدم كمراكز مجتمعية للصمود. كما ستقود الأنظمة الشمسية للاستخدامات الإنتاجية عمليات الضخ والتحلية والمعالجة الزراعية وحفظ الأسماك، رابطاً الطاقة مباشرة بالأمن المائي والغذائي. وستُدعَم المؤسسات لوضع المعايير والسياسات وآليات التمويل لضمان استدامة أسواق الطاقة اللامركزية.

- لضمان الاستدامة والتوسع سيُستثمر في بناء القدرات والتخطيط، مع تدريب السلطات المحلية وجمعيات مستخدمي المياه والمجتمعات على التشغيل والصيانة والتخطيط المرن. كما سيُعدّ المشروع خططاً متكاملة للمياه واستخدام الأراضي على مستوى المديريات، ودراسات استثمارية للتوسع في الطاقة المتجددة، وخططاً للتكرار، مدعومة بمنظومة متابعة وتقييم قوية.

يتبنى المشروع استراتيجية مترابطة يدعم فيها الطاقة المتجددة المياه وسبل العيش، وتؤمّن المياه الزراعة والنظم البيئية، وتقلل سبل العيش المرنة من الفقر والنزوح والنزاعات. وتُعد المدارس محاور أساسية للصمود، تحمي الأطفال وتخدم كمراكز مجتمعية. وتشمل النتائج المتوقعة تحسين الأمن المائي لمئات الآلاف من الأسر، وزيادة غلة المحاصيل بنسبة تصل إلى 30%، وإنعاش سلاسل القيمة، وتقليل الانبعاثات عبر خفض استخدام الديزل، وتوفير مدارس مرنة مناخياً. كما سيُعزَّز تمكين النساء والشباب والنازحين عبر المشاركة في سلاسل القيمة، والتدريب، وسبل العيش المدعومة بالطاقة المتجددة.

Introduction

CHAPTER 1

Introduction

6.1 Background and Rationale

Yemen faces a complex interplay of protracted conflict, fragility, and accelerating climate change. The ongoing conflict has created one of the world's worst humanitarian crises, with 80 % of households lacking reliable access to basic services and livelihoods. Climate change intensifies these vulnerabilities, compounding water scarcity, food insecurity, fragile infrastructure, and public health risks. Approximately half of Yemen's population is directly exposed to major climate hazards—including extreme heat, drought, and flooding—while one quarter simultaneously suffer from food insecurity and climate shocks, particularly in conflict-affected districts. These combined pressures erode resilience and deepen multidimensional poverty, disproportionately affecting women, youth, and displaced populations.

The economic implications of climate change are severe. Without adaptation, Yemen's annual GDP is projected to decline by 3.9 % by 2040, driven by reduced agricultural productivity, infrastructure damage, and health impacts. Climate change could also result in more than US$5 billion in additional health expenditures by 2050, overwhelming an already fragile system. Conversely, improved water management and climate-smart practices could raise agricultural yields by up to 13.5 % between 2041 and 2050, while sustainable coastal and fisheries management could help mitigate a projected 23 % decline in marine production[1].

Climate-induced migration is a growing reality. Prolonged drought and water scarcity—affecting nearly 50% of Yemenis—undermine agricultural systems and force rural households to migrate in search of food and income. Between 2019 and 2022, floods and cyclones displaced more than 300,000 people, while recurrent droughts continue to drive both seasonal and permanent migration in the highlands and coastal zones. Limited access to energy where only 47% of the population has reliable electricity, further constrains adaptive capacity, restricting water pumping, cooling, and livelihood activities. Climate-related disasters are now estimated to account for 10–15% of internal displacement annually, compounding conflict-related migration and intensifying humanitarian needs[2].

Despite these risks, targeted adaptation measures present opportunities to stabilize Yemen's development trajectory. Improved water management, soil conservation, and climate-smart agriculture could raise agricultural yields by up to 13.5 % between 2041 and 2050, bolstering food security and nutrition. The fisheries sector, at risk of up to a 23 % decline in production, underscores the urgency of sustainable practices and stronger coastal management. At the same time, Yemen's rapidly growing urban areas are

[1] Yemen Country Climate and Development Report: https://documents1.worldbank.org/curated/en/099111824082514197/pdf/P5006381e44f0109719b871d68f6833548e.pdf

[2] Migration, Environment and Climate Change in Yemen: https://publications.iom.int/books/migration-environment-and-climate-change-yemen

increasingly exposed to climate-related disasters, highlighting the need for resilient infrastructure and disaster risk management.

Besides, renewable energy offers one of the most transformative adaptation options. Distributed solar PV and other clean technologies can provide reliable electricity to desalinate and supply water in both rural and urban areas, ensuring equitable access during periods of scarcity. Clean energy can also sustain cooling systems in education and health facilities, helping to reduce mortality and morbidity during heatwaves. By reducing dependence on volatile fossil fuel imports, renewable energy strengthens adaptive capacity across sectors and directly benefits vulnerable groups by ensuring stable access to water, health services, and livelihood opportunities.

An integrated and comprehensive adaptation approach is therefore essential. Building resilience in Yemen requires a nexus-based framework that connects water, food and agriculture, energy, and ecosystems. This approach is justified by the interdependence of these sectors: water scarcity directly undermines agricultural productivity and food security; degraded ecosystems accelerate erosion and reduce groundwater recharge; and limited access to clean energy restricts the provision of water, health, and livelihood services. By addressing these linkages in a coordinated manner, interventions can generate multiple co-benefits, improving agricultural yields, securing safe water supplies, strengthening public health, diversifying livelihoods, and reducing displacement pressures. Embedding this framework within institutional capacity building, local participation, and inclusive governance ensures that scarce resources are used efficiently, avoids fragmented interventions, and builds systemic resilience to the combined impacts of climate change and conflict.

Against this backdrop, the proposed project "**Building Climate Resilience of Vulnerable Groups in Rural and Urban Areas of Yemen"** is designed to put the nexus-based adaptation approach into practice by improving water security, promoting climate-smart agriculture and resilient livelihoods, restoring ecosystems, and expanding the use of renewable energy for essential services such as education facilities, and productive activities in water security and sustainable livelihoods. At the same time, the project will strengthen institutional capacity and coordination mechanisms to maintain climate resilience and empower local communities in decision-making. Together, these interventions aim to reduce climate risks, curb the drivers of displacement and poverty, and lay the foundation for a more resilient and sustainable development pathway in both rural and urban areas of Yemen.

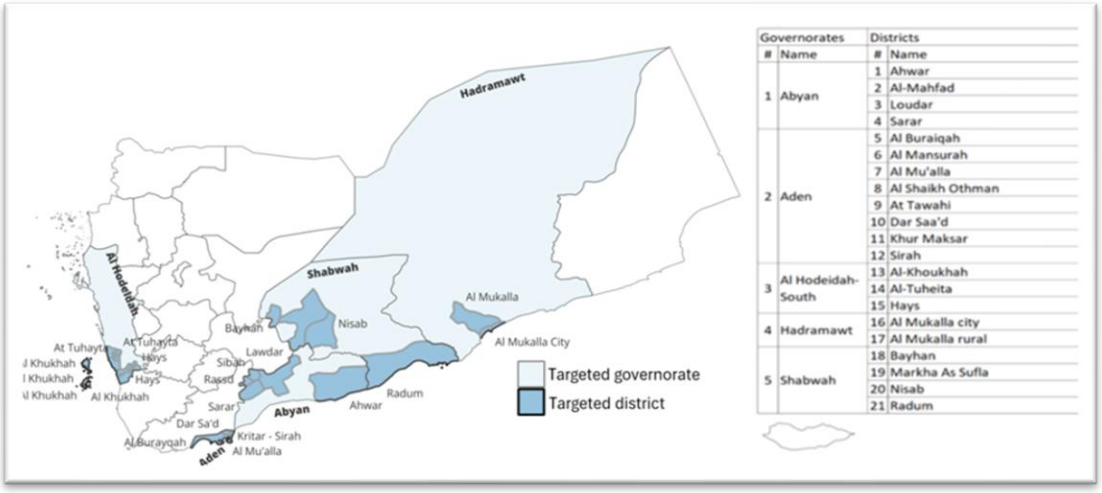
6.1 Objectives of the Baseline report

The baseline report will support the development of the Preparation Grant (PPG) to generate the technical, institutional, and evidence-based foundations required for the design of the full-sized GEF-08 project. Through comprehensive assessments, stakeholder consultations, and feasibility assessment, the PPG will refine and validate interventions on water management, agriculture and ecosystems, renewable energy for schools, water security and sustainable livelihoods, and institutional capacity building. This ensures that the final project design is context-specific, technically sound, and aligned with both national priorities and GEF climate adaptation objectives. The specific objectives are as follows:

1. Assess climate change vulnerability at governorate and district levels by analyzing exposure to key hazards, population sensitivity, and socioeconomic drivers of risk.
2. Evaluate water and agriculture systems by reviewing resources, infrastructure, irrigation, and ecosystems, and identifying adaptation options in water, agriculture and livelihoods.
3. Evaluate the potential of renewable energy deployment for resilience by assessing the potential of mini and off-grid solar and other technologies to strengthen schools, water security, and livelihoods.
4. Identify institutional, technical, and knowledge gaps by analyzing, governance structures, and capacity needs, and providing an evidence base for integrated project interventions.

6.1 Scope of the Report

The project "Building Climate Resilience of Vulnerable Groups in Rural and Urban Areas of Yemen" seeks to enhance adaptive capacity in five governorates (Aden, Al-Hudaydah, Abyan, Shabwah, and Hadramawt/Al-Mukalla) through integrated interventions in water, agriculture, renewable energy, ecosystems, and institutional capacity building.



Governorates		Districts	
#	Name	#	Name
1	Abyan	1	Ahwar
		2	Al-Mahfad
		3	Loudar
		4	Sarar
2	Aden	5	Al Buraiqah
		6	Al Mansurah
		7	Al Mu'alla
		8	Al Shaikh Othman
		9	At Tawahi
		10	Dar Saa'd
		11	Khur Maksar
		12	Sirah
3	Al Hodeidah-South	13	Al-Khoukhah
		14	Al-Tuheita
		15	Hays
4	Hadramawt	16	Al Mukalla city
		17	Al Mukalla rural
5	Shabwah	18	Bayhan
		19	Markha As Sufla
		20	Nisab
		21	Radum

Map 1: Targeted Governorates and Districts

The scope covers four main components:

1. **Water Management:** Assessment and implementation of integrated water resource management solutions in Shabwah and Abyan, including rainwater harvesting, storage, reuse of wastewater, treated and desalinated water, and ecosystem restoration to reduce vulnerability to droughts, floods, and land degradation as well as enhancing the water security by deployment of innovative technologies in some districts in Aden and Al-Hudaydah.

2. **Agriculture, Livelihoods, and Ecosystems:** Deployment of Climate-smart agriculture practices, ecosystem-based adaptation (EbA), soil and land restoration, and diversified income-generating activities to strengthen food security and community resilience in Shabwah and Abyan.

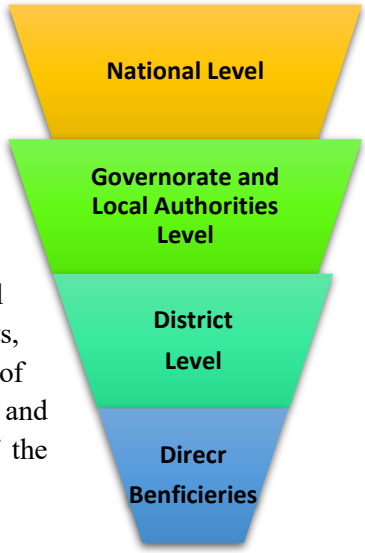
3. **Renewable Energy for Climate-Resilient Practices:** "Deployment of decentralized renewable energy systems in schools and surrounding communities (Aden, Hadramawt/Al-Mukalla, and Al-Hudaydah), as well as in water fields, to ensure sustainable energy for education, reliable access to safe water, and to support the national transition away from diesel dependency while strengthening resilient and sustainable livelihood value chains in Shabwah and Abyan.

4. **Capacity Building and Knowledge Management:** Strengthening institutional, technical, and community capacities on climate adaptation; embedding climate change into education curricula; developing training programs; and promoting knowledge sharing, replication, and scaling of successful models across all target governorates.

Accordingly, this report aims to provide a baseline analysis and assessment of the targeted governorates and districts to identify their climate change vulnerabilities and to develop a justifiable list of priority interventions. In this regard, the report will include different sectors as follows:

- Present climate baselines, socioeconomic conditions, and future projections to develop an integrated vulnerability narrative, and analyze major hazards, exposure, sensitivity, and adaptive capacity including tables, maps, and vulnerability rankings of districts.
- Assess water resources, existing irrigation infrastructure, and related challenges and capacity-building needs, and prioritize adaptation options in the targeted areas.
- Evaluate agricultural practices, ecosystem functions, and livelihood systems in the targeted districts, and develop a list of interventions for climate-resilient agriculture, restored ecosystems, and diversified sustainable livelihoods.
- Identify potential models for renewable energy deployment through mini-grids and off-grid systems to support climate-resilient practices in education, water security, and income-generating livelihoods.
- Assess institutional and technical capacity gaps to strengthen climate governance, analyze national plans and strategies while mapping the institutional landscape, evaluate governance and coordination mechanisms to identify overlaps and gaps, and develop a stakeholder engagement plan with capacity-building activities based on stakeholder mapping and identified needs.
- Develop an Environmental and Social Management Framework (ESMF), including environmental and social baselines, assessments of risks and mitigation measures, a gender action plan, and alignment with GEF, UNDP, and Yemeni environmental and social safeguards.

6.1 Methodology



The preparation of the baseline reports started with a desk review of all the available documents, reports and studies. Then, it was guided by a participatory, multi-stakeholder engagement process designed to ensure technical robustness, policy alignment, and local ownership [3]. The process combined national-level coordination with localized assessments in targeted governorates, districts, and villages. It involved technical consultations, policy discussions, participatory workshops, site visits, stakeholder meetings, and surveys, all complemented by the application of Multi-Criteria Analysis (MCA) to prioritize interventions. Gender, youth, and internally displaced persons (IDPs) were considered at every stage of the process to ensure inclusivity and equity.

1..1 Stakeholder Consultation

1. **Focused Technical Group Discussions with Line Ministries**
   - ✓ Initial consultations were held with technical experts from key line ministries to define sectoral priorities in water, agriculture, energy, and ecosystems.
   - ✓ These discussions identified data gaps, institutional challenges, and opportunities to align with national climate and development strategies.
2. **National-Level Meetings with Ministries and Entities**
   - ✓ Broader meetings were convened at the national level with ministries, agencies, and institutions to validate the technical findings.
   - ✓ These sessions ensured coherence with existing national plans, policies, and strategies, while clarifying institutional roles and coordination mechanisms.
3. **Workshops in Targeted Governorates**
   - ✓ Participatory workshops were organized in the five targeted governorates to capture regional perspectives and climate adaptation needs.
   - ✓ Local authorities, CSOs, community representatives, and private sector actors contributed to identifying vulnerabilities and proposing interventions.
4. **Site Visits at District and Village Levels**
   - ✓ Field missions were carried out to directly observe vulnerabilities, sectoral challenges, and adaptive capacities at the local level.
   - ✓ The visits included assessments of water infrastructure, agricultural practices, schools, renewable energy opportunities, and local livelihood systems.
5. **Stakeholder Consultations and Surveys**
   - ✓ Structured consultations and surveys engaged diverse groups, including women, youth, and IDPs, to gather insights on vulnerabilities and coping mechanisms.
   - ✓ This provided both qualitative and quantitative evidence for designing context-specific interventions.
6. **Cross-Cutting Considerations**
   - ✓ Gender, youth, and IDPs were systematically integrated across all stages of engagement.
   - ✓ Environmental and social safeguards, potential risks, and co-benefits were assessed in line with GEF and UNDP requirements to strengthen accountability and sustainability.

[3] Please refer to the Stakeholder Engagement Plan (SEP) for more details

1..2 Application of Multi-Criteria Analysis (MCA)

The MCA is applied to prioritize interventions by identifying climate risks in each targeted district and assessing technical feasibility, climate rationale, socioeconomic benefits, ecosystem impacts, and gender responsiveness, with scoring and ranking conducted in collaboration with national and local stakeholders to ensure transparency, inclusivity, and consensus on priorities. This will be achieved through tow steps as follows:

1. Identification of climate hazards and risks in each district using the following criteria:
   - ✓ Severity and frequency of impacts(%25)
   - ✓ Population exposed to risk(%20)
   - ✓ Sensitivity of water, agriculture, ecosystems, and infrastructure(%20)
   - ✓ Current adaptive capacity(%20)
   - ✓ Presence of vulnerable groups (15%)

2. Prioritization of the interventions in each district as follows:
   - ✓ Enhancing adaptive capacity to climate change(%25)
   - ✓ Impact on water and food security(%20)
   - ✓ Environmental and social impact(%10)
   - ✓ Technical feasibility, institutional readiness, and ease of implementation(%15)
   - ✓ Effectiveness, sustainability, and multiple benefits(%15)
   - ✓ Number of beneficiaries (15%)

Through this two-step MCA process, interventions were systematically scored and ranked against weighted criteria, with active participation from national and local stakeholders to guarantee openness, broad participation, and collective agreement. The outcomes of the MCA are further verified through site visits to ensure that prioritized interventions reflect on-the-ground realities. The result is a ranked list of interventions for each district, supported by a clear climate rationale, socioeconomic benefits, ecosystem co-benefits, and alignment with GEF indicators.

Climate change Vulnerability

CHAPTER 2

Climate change Vulnerability

6.1 Yemen overview of climate and climate change vulnerability

Yemen covers an area of 527,970 km² [4]and has a coastline of 2,200km along the Arabian Sea, the Gulf of Aden, and the Red Sea. Yemen can be divided according to its natural environments, which are closely linked to climate variability and associated agricultural livelihoods, into five regions:

2..1 Coastal Plains

It is a ~10% of Yemen's land area[5], extend on the area of Red sea, Gulf of Aden, Arabian sea and Indian Ocean. Average temperatures are 30–40°C (highest in Tihama Plain)[6] and rainfall as low as 50 mm/year in Al Hudaydah[7].

The key features:

A) Valley Estuaries: Highly productive support around 35% of Yemen's irrigated agriculture (e.g., Tihama Plain contributes ~20% of national sorghum production)8. The main threats to this region are saltwater intrusion which affects 30% of arable land in coastal zones.9

B) Drylands: Cover around ~60% of Abyan and Hadhramaut coasts[10], and host pastoralism communities that support 25% of livelihoods in these regions[11].

C) Salt Marshes: This region is highly degraded with 15% increase in salinization since 2000 due to reduced freshwater flow[12].

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[4] World Bank Climate Portal. (2023). *Yemen climate data: Rainfall and temperature trends*. https://climateknowledgeportal.worldbank.org

[5] FAO (Food and Agriculture Organization of the United Nations). (2020). Yemen: Land use *and agricultural zoning*. AQUASTAT Country Profile. http://www.fao.org/aquastat

[6] **UNDP (United Nations Development Programme).** (2021). *Climate change adaptation in Yemen's highlands*. https://www.ye.undp.org

[7] WB, 2023

[8] **FAO. (2021). The role of valley estuaries in Yemen's food security. FAO Agricultural, Development Paper**

[9] **ICARDA (International Center for Agricultural Research in the Dry Areas). (2020). Water scarcity and agricultural abandonment in Yemen's highlands. ICARDA Research Bulletin**

[10] **UNEP (United Nations Environment Programme),** (2021). *Desertification and land degradation in Yemen*. https://www.unep.org

[11] **IFAD (International Fund for Agricultural Development).** (2022). *Pastoralism and rural livelihoods in Yemen's drylands*. IFAD Policy Paper

[12] **ACSAD (Arab Center for the Studies of Arid Zones and Dry Lands).** (2019). *Assessment of land degradation and salinization in Yemen's coastal plains*. ACSAD Technical Report No. 45

D) Urban Centers: It is not highly populated and high population centered on the big cities as Aden, Al Mukalla and Al Hodiedah host ~4 million people[13].

Climate Risks: The main risks in this region are flood exposure with 40% of coastal cities lie in high-risk flood zones[14]. Heath stress with Aden's average summer temps rose by 2.1°C since 1980[15].

2..2 Highlands (1,000–3,600 m elevation)

The highlands are the receive a highest amount of rainfall 500–800 mm/year (highest in Ibb Governorate)[16]. The temperature is the lowest in Yemen 10–25°C (cooler than coastal zones)[17].

Key Features:

A) Agricultural Terraces: It one of the important historical traditional practices in Yemen and cover almost ~40% of arable land in Yemen[18]. This system has been declining by 30% abandoned due to water scarcity[19].

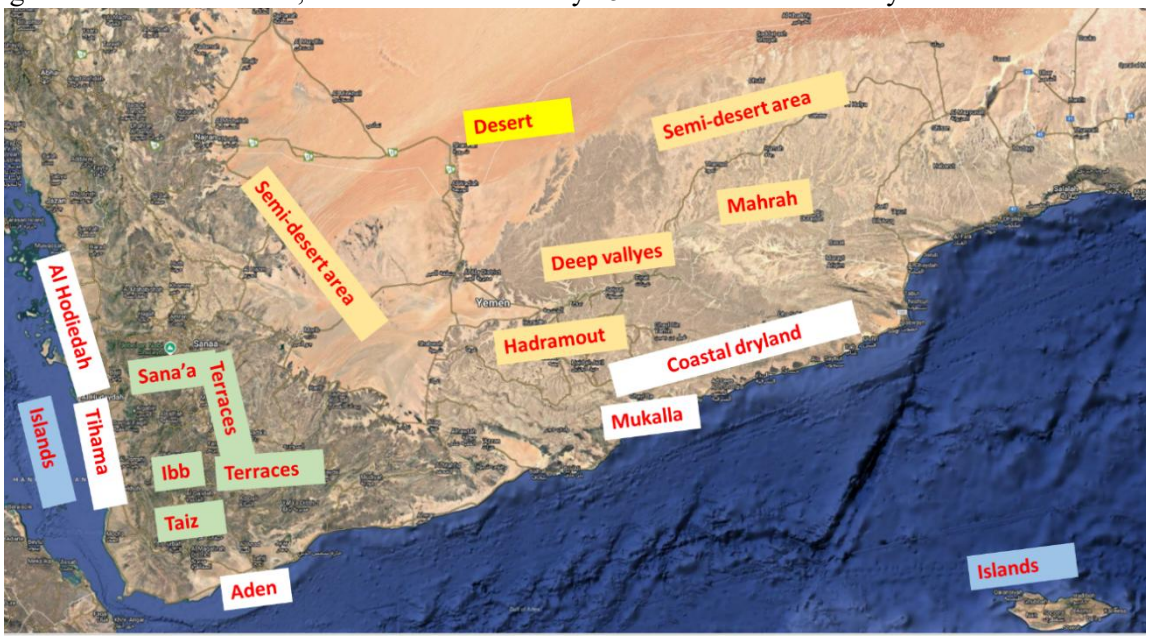
B) Dry Highlands: This region famous by coffee production, Taiz and Ibb produce 90% of Yemen's coffee[20], but yields dropped 50% since 2000 due to drought[21].

[13] **UN-Habitat**. (2023). *Urbanization and climate risks in Yemeni coastal cities*. https://unhabitat.org/yemen
[14] **GFDRR (Global Facility for Disaster Reduction and Recovery)**. (2022). *Yemen urban flood risk assessment*. World Bank Group. https://www.gfdrr.org
[15] World Bank Climate Portal. (2023). *Yemen climate data: Rainfall and temperature trends*. https://climateknowledgeportal.worldbank.org
[16] FAO (Food and Agriculture Organization of the United Nations). (2020). Yemen: Land use *and agricultural zoning*. AQUASTAT Country Profile. http://www.fao.org/aquastat
[17] **UNDP (United Nations Development Programme).** (2021). *Climate change adaptation in Yemen's highlands*. https://www.ye.undp.org
[18] ICARDA (International Center for Agricultural Research in the Dry Areas). (2020). *Water scarcity and agricultural abandonment in Yemen's highlands. ICARDA Research Bulletin.*
19 World Bank. (2022). Yemen: Agricultural terraces and water scarcity. *MENA Development Report. https://www.worldbank.org/en/country/yemen*
[20] FAO (Food and Agriculture Organization of the United Nations). (2023). *Coffee production systems in Yemen: Climate vulnerabilities and adaptation strategies*. FAO Agricultural Policy Paper No. 12. http://www.fao.org/publications
21 MENA Drought Monitor. (2023). Yemen drought risk assessment. *Regional Climate Center*

C) Cities: The highland hosts the highest population of Yemen, some cities like Taiz and Sana'a have water stress, Sana'a may exhaust groundwater by 2030[22].

2..3 Plateaus (Hadhramaut, Mahra)

The plateaus have low rainfall especially towards desert <100 mm/year (driest region)[23]. This region has a unique feature, Hadhramaut Valley supports 80% of Yemen's date production[24]. Due the characteristics of this region it faces soil erosion; the flash floods destroy 15% of farmland annually[25].



Map2 : Demonstrate the main topography features of Yemen topography

a) **Plateaus:** These are semi-arid sedimentary environments where scattered shrubs, herbs, and grasses are widespread, and the population usually relies on grazing.

b) **Deep valleys**: These represent a unique environment in Yemen, where deep valleys with small banks are formed and are highly susceptible to erosion due to floods. These valleys are popular for palm and jujube tree cultivation, as well as beekeeping. The most famous of these valleys is Hadhramaut Valley, which divides the plateau into a northern and southern part. Among the most famous valleys in these plateaus are Wadi Hajar, Wadi Amd, and Daw'an, among others. These areas are considered fertile. There are some mountains adjacent to the plateau towards the Arabian Sea, the most important of which is Kor Siban, located in the countryside of Mukalla.

22 NWRA (National Water Resources Authority, Yemen). (2021). Groundwater depletion in Sana'a Basin. *NWRA Technical Report*
23 FAO ,2020
24 WFP (World Food Programme). (2022). Food security and date production in Hadhramaut Valley. *https://www.wfp.org/countries/yemen*
25 UNDP. (2023). Flash flood impacts on Yemen's plateaus. *Yemen Resilience Report.*

c) **Semi-desert areas**: These are the plateau areas adjacent to the Rub' al Khali desert, where water and population activity are scarce. d) Population centers: Important cities such as Sayun, Shibam, and Tarim are located at the beginning of Hadhramaut Valley, while small towns are found in the subsidiary valleys.

2..4 Deserts

The Rub' al Khali covers ~25% of Yemen[26], and has extreme temperature up to 50°C in summer[27].

2..4.1 Islands & Marine Zones:

Yemen has more than 112 islands. Socotra Archipelago host high biodiversity, 37% of plant species are endemic[28], also face a coral bleaching which increased by 40% since 2015[29]. Yemen also depends on fishery sector with 12% of Yemen's GDP relies on coastal fisheries[30].

Yemen is acutely vulnerable to climate change, which acts as a threat multiplier to its fragile context of conflict and economic collapse. The primary physical drivers are rising temperatures (increase of over 2°C since the mid-20th century, projected to rise up to 4.5°C by 2100), erratic rainfall (15-25% decrease in highlands, but increased storm intensity), and sea-level rise (0.6-1.1m by 2100), which is causing saltwater intrusion into 45% of coastal aquifers.

These changes catalyze severe downstream impacts: catastrophic floods have caused over $1 billion in damages, staple crop yields have dropped by 35-50%, and key aquifers are depleting at rates up to 8 meters per year. This environmental degradation intersects with a shattered socio-economic system. The economy has been halved since 2015, with over 80% poverty rates and 21.6 million people requiring humanitarian aid. Climate shocks exacerbate food insecurity for 17.6 million people, damage critical infrastructure (e.g., the port of Hudaydah, which handles 70% of imports), fuel resource-based conflicts, and strain a collapsed health system by spreading disease.

Despite international commitments and frameworks like the National Adaptation Plan, Yemen's adaptive capacity is critically low due to conflict. While projects exist to build resilience (e.g., in water management and sustainable livelihoods), they are insufficiently scaled. Ultimately, climate vulnerability is inextricably linked to the humanitarian crisis, making climate adaptation measures essential for saving lives and building a foundation for future stability.

[26] **NASA Earth Observatory**. (2023). *Desertification trends in the Arabian Peninsula*. https://earthobservatory.nasa.gov
[27] **NOAA (National Oceanic and Atmospheric Administration).** (2022). *Extreme temperature analysis for the Rub' al Khali*. https://www.ncdc.noaa.gov
[28] **UNESCO**. (2023). *Socotra Archipelago: Biodiversity and conservation status*. https://whc.unesco.org
[29] **GCRMN (Global Coral Reef Monitoring Network).** (2022). *Status of coral reefs in the Red Sea and Gulf of Aden*. IUCN Report
[30] WB, 2023

6.1 Climate change Vulnerability

6.1 Target Governorate Comate Change Vulnerability

2..1 Climate Change Vulnerability Shabwah Governorate

2..1.1 Climate and Socio-Economic Profile Shabwah Governorate

Socioeconomic Context

Shabwah, one of Yemen's largest governorates, approximately 42,584 square kilometers with a diverse topography ranging from coastal plains to northern mountains and eastern deserts, has an arid climate and a population of over 676,409[31] people heavily dependent on climate-sensitive livelihoods. While its economy is often perceived as limited, it is underpinned by critical yet vulnerable sectors: the primary sources of income are rain-fed agriculture (date palms, cereal, fodder, fruits, and vegetables), pastoralism and livestock, and famed honey production, while coastal communities like those in Radhum rely on fishery. Furthermore, Shabwah is home to some of Yemen's most important oil and gas infrastructure, most notably the Masila oil fields and the Liquefied Natural Gas (LNG) facility at Balhaf, which anchor its industrial sector. Like other regions, its urban centers are active in trading and services, with the economy also being significantly supported by expatriate remittances—a vital financial lifeline from its diaspora. Despite possessing untapped tourism potential from ancient archaeological sites and its ports like Bir Ali, these opportunities remain underdeveloped due to instability and a lack of infrastructure.

Climate Change Profile

Climate change scenarios (past and future), for main climate change indicators for Shabwah governorate, the table generated from FAO, WB reports[32]

Table 1: Climate change scenarios (past and future), for main climate change indicators for Shabwah governorate

Climate Indicator	Past Observation	Future Projection
Avg. Temp	Partly in Desert and Internal Plateau. Experienced significant warming. Yemen-wide average increase of ~1.4°C (1976-2019). Warming rates are among the highest globally	Projected increases of +4.0 to +4.5°C (interior zone projection). Consistently ranks among the highest projected increases in the Middle East

[31] Statistical Yearbook 2022, Central Statistical Organization - Yemen

[32] Climate Impact Potential Assessment Yemen EPA FAO GCF 2023, Country Climate and Development Rerport CCDR 2024 WB and Climate risk Country Profile WB 2023

Tmax	Eastern parts show a high rate of increase (Fig 5b), estimated at +0.04°C/yr or more (~+1.4°C+ total). Heatwaves have become more intense, frequent, and longer	Projected to be in the zone of highest increase (+4.0 to +4.5°C) for Tmax
Precipitation	Very low rainfall (<100mm/yr). No statistically significant trend observed in this region (Fig 3b). High inter-annual variability, with frequent failure of seasonal rains.	Expected to remain very dry. A slight decrease (~10-20%) or no change is most likely, exacerbating aridity. Increased intensity of individual rainfall events, raising flash flood risk despite overall drier conditions
Very Warm Days (≥35°C	High baseline in northern parts (100+ days/yr). Significant increase observed (Fig 9b).	Projected to see a large increase (+60 to +80 additional days/year)
Sea Level Rise	*Not directly applicable to most of Shabwah, but critical for coastal areas like Bir Ali*	For the Gulf of Aden coast: projected rise of 0.3-0.6m by 2100, increasing coastal erosion and saline intrusion into groundwater
Key Risks	*Extreme drought, desertification, depletion of groundwater, sand and dust storms. High vulnerability due to dependence on climate-sensitive agriculture and water resources*	Increased frequency and severity of droughts, making agriculture increasingly non-viable, heightened resource competition. Projected yield losses for key crops (sorghum, maize). Significant threat to water security and livelihoods, potentially increasing displacement and conflict over scarce resources

Dominant Agro-Ecological Zone: Desert (north) and Internal Plateau (south)

Under the SSP3-7.0 scenario (a pathway marked by regional rivalry and uneven development), projections for Shabwah are severe:

- Temperature: Mean temperature increase of +1.8°C with 90–110 days per year exceeding 35°C.
- Drought: A projected 10-15% reduction in groundwater recharge by 2050, critically threatening the main source for irrigation and drinking water.

- Flooding: A 25% increase in the frequency of 100-year floods (pluvial/fluvial), raising the risk of destructive flash floods in wadis like Bayhan.

Overall Vulnerability Narrative

Shabwah's vulnerability is a story of compound risks: intensifying climate hazards converging with high socio-economic fragility. Projected increases in extreme heat, drought, and flooding will directly undermine the agricultural and pastoral foundations of the local economy. This will lead to diminished crop yields, loss of livestock, and further depletion of critical groundwater resources. The consequences will be severe: heightened food insecurity, increased poverty, and potential displacement as livelihoods become untenable. The governorate's limited adaptive capacity, exacerbated by poverty, population pressures, and weak infrastructure, means this climate impacts will likely amplify existing challenges, creating a vicious cycle of environmental degradation and human vulnerability.



Map3 : Climate change vulnerability to flood (Red: high risk, Dark Yellow: Middle), climate change vulnerability assessment to district level for four selected Yemeni governorates (EP-FAO, 2024)

Table 2: Shabwah districts Hazard & Risk Ranking by priorities (from literatre and consultation)

District	Drought	Flood	Water scarcity	Water salinity	Heat waves	Soil erosion	Rain variability
Bayhan	1	2	3	7	6	4	5
Markhah Al sofla	5	1	4	7	6	2	3
Nisab	1	7	4	6	2	5	3
Radhum	4	1	5	2	7	3	6

This vulnerability assessment table reveals that each district in Shabwah faces a distinct hierarchy of climate threats, necessitating highly targeted interventions. In Bayhan, the paramount concerns are drought and flooding, requiring integrated water management strategies like water harvesting and flood defenses. Markhah Al Sofla's greatest risk is flooding, making it the priority for drainage and early warning systems. Nisab's primary challenges are severe drought and heat waves, demanding immediate focus on drought-resistant agriculture and heat mitigation. Conversely, the coastal district of Radhum must prioritize combating flooding and critical water salinity, necessitating investments in desalination, coastal protection, and salt-tolerant crops. Overall, the data underscores that a uniform response is ineffective; resources must be allocated based on this specific risk profile to build resilience where it is needed most.

***District**-Level Climate Change Vulnerability Assessments*

i. Bayhan Climate Change Vulnerability Assessment

1. Overview

The arid landscapes of Yemen's Shabwah Governorate. The Bayhan district, covering an area of 616 square kilometers[33], is a region home to 75,770 inhabitants[34], where life is intrinsically tied to the land and the precious flow of water. For centuries, its social and economic fabric has been woven around the fertile expanse of Wadi Bayhan, a valley supporting approximately 7,500 hectares of cultivable land. This agricultural wealth has established the district as a vital regional breadbasket.

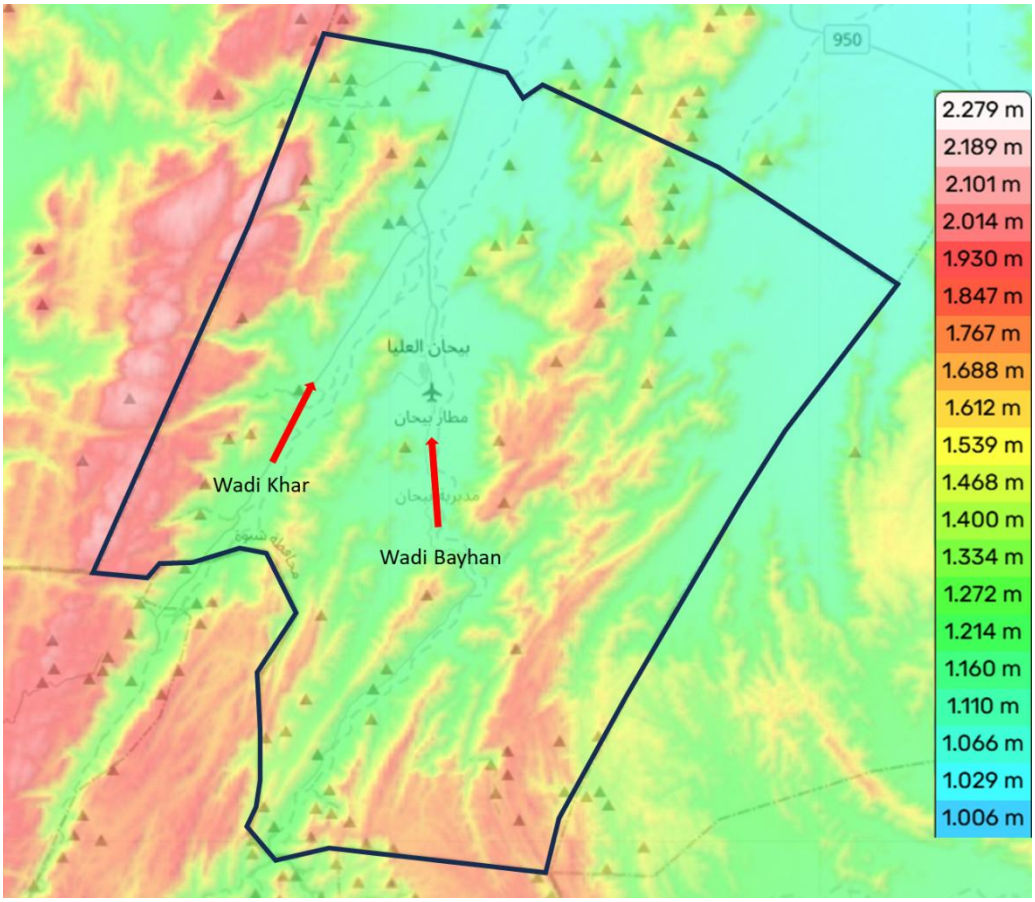
The story of Bayhan is fundamentally one of water. The primary source of income for its tribal-organized population is a centuries-old, sophisticated spate irrigation system, a testament to deep traditional knowledge designed to harness unpredictable flash floods for cultivation. This deep-rooted agricultural dependency is both the district's greatest strength and its most profound vulnerability.

Despite its potential, Bayhan contends with severe socio-economic fragility. High rates of poverty and unemployment are reported across the southern governorates, and Bayhan is no exception. This economic precarity means that the community's resilience is exceptionally thin; a single failed season or destructive

[33] Statistical Yearbook 2022, Central Statistical Organization - Yemen

[34] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

flood can push vulnerable households into crisis levels of food insecurity. Thus, the stability of Bayhan's water-based economy remains the paramount determinant of its community's well-being and stability.



Map 4: Bayhan districts with elevation, shows wadi Bayhan and wadi Khar

2. Major Hazards

Hazards and its ranking for Bayhan district – Shabwah governorate

Table 3: Major hazards for Bayhan district governorates can be summarized as follow:

Hazard & Risk	Ranking	Explanation & Context
Drought	1	The district's dry climate (avg. 50mm/yr in lower areas like Al-Sha'b area, ~250mm in highland catchments)[35] makes it chronically vulnerable. Periods of low rainfall directly reduce spate flows in the Wadi Bayhan system and critically limit recharge of the main

[35] Girgirah, A.A.; Maktari, M.S.; Sattar, H.A.; Mohammed, M.F.; Abbas, H.H.; Shoubihi, H.M. Wadi Development for Agriculture in PDR Yemen. 2021. Available online: https://floodbased.org/wp- ontent/uploads/2021/05/Wadi-development-for-agriculturein-PDR-Yemen.pdf

		aquifer, which is the lifeline for irrigation. This is the paramount challenge, threatening the 7,500 hectares of cultivable land[36].
Flash Flood	2	Intense rain in the Hashid highland catchments causes destructive flash floods coursing through Wadi Bayhan and its tributaries like Wadi Fadhah. These events damage traditional infrastructure (e.g., the Asr Dam, Jarban barrier), erode soil, and destroy crops. Floods occur with rainfall exceedingly just 17mm[37], making the system highly exposed.
Water Scarcity	3	A compound hazard. Physical scarcity is worsened by the deterioration of water harvesting systems. For example, the silting and damage to the Jarban Canal and Bir Lahmar systems reduce the ability to capture floodwater. Over-extraction of groundwater, with well numbers increasing, depletes the aquifer.
Soil Erison	4	Directly linked to flash floods. The 1996 flood event dramatically widened the wadi course, eroding the renowned fertile topsoil from farms in areas like Al-Masna'ah and Qatnah, degrading the land that supports key crops like dates, wheat, and citrus[38].
Rain Variability	5	The irregular timing and distribution of rains disrupt the planting cycles for sorghum and millet. A delay in the rains can cause crop failure, while intense, short bursts paradoxically intensify flood risk without effectively recharging the aquifer.
Heat Waves	6	Increasing temperatures accelerate evaporation from soil and surface water in reservoirs, increasing the water requirements for key crops like citrus and alfalfa, thereby compounding water scarcity issues
Water Salinity	7	Over-extraction from the aquifer is leading to falling water tables, which can induce salinity, threatening productivity in date groves and gardens, particularly in the lower parts of the wadi near Suq Bayhan.

[36] ibid

[37] Girgirah, A.A.; Maktari, M.S.; Sattar, H.A.; Mohammed, M.F.; Abbas, H.H.; Shoubihi, H.M. Wadi Development for Agriculture in PDR Yemen. 2021. Available online: https://floodbased.org/wp- ontent/uploads/2021/05/Wadi-development-for-agriculturein- PDR-Yemen.pdf (accessed on 31 December 2023).

[38] Documented study, Traditional Irrigation Systems and Methods of Water Harvesting in Hadramout and Shabwah Governorate, 1996, EPA, Aden University (Netherland, MetaMeta)

The drought and flood work together to weakness the agriculture activity.

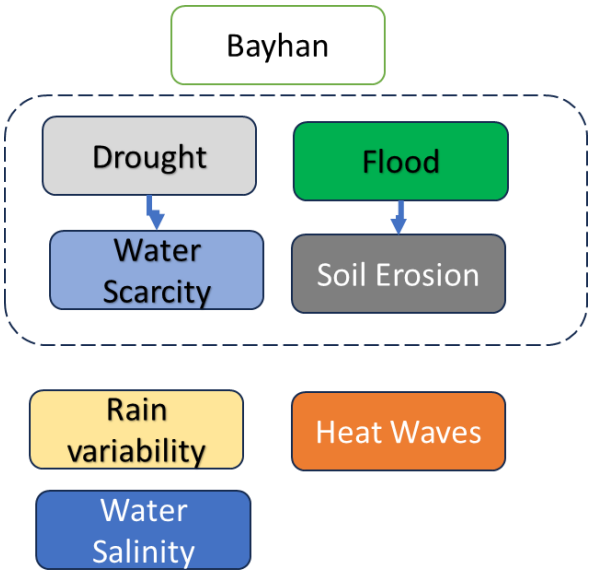


Figure 1: Bayhan climate change hazards/risks interlink, drought and flood are the main climate change drivers.

3. Exposure

Exposure is intensely concentrated in the Wadi Bayhan floor. The agricultural towns of Suq Bayhan (the district capital), Al-Ain, Qatnah, and Al-Masna'ah are all situated directly along the wadi to access water and farmland. This places their populations, homes, and market infrastructure directly in the path of flash floods. The entire agricultural infrastructure—including the historic Asr Dam, the Jarban intake, and the network of canals serving thousands of farms—is designed to intercept floodwater, making it fundamentally exposed. The 7,500 hectares of cultivable land, the district's primary economic asset, are fully exposed to both drought and flood hazards.

4. Sensitivity

The high dependence on agriculture and the precise functioning of the spate irrigation system makes Bayhan extremely sensitive to climatic shifts.
The entire socio-economic structure is built upon the wadi's fertility. For example, a failure of the spate floods to arrive means the sorghum and millet crops in the upper wadi areas near Al-Ain will fail. A reduction in flood volume means less recharge for the aquifer, causing wells to run dry in villages like Al-Sha'b, threatening the citrus and date orchards that depend on groundwater irrigation. This direct link between climate and output threatens food security for a population where reports indicate parts of Shabwah are in IPC Phase 3 (Crisis).

The sensitivity is critically amplified by the degradation of socio-economic institutions that once managed risk. The deep-rooted customary laws (traditions) that governed the equitable distribution of water and maintenance costs for systems like the Jarban Canal were a key resilience mechanism. Violations of these traditions, such as illegal upstream water diversion or encroachment on the floodplain, have drastically increased vulnerability. The 1996 flood disaster serves as a stark example, where such encroachment

exacerbated destruction in Suq Bayhan[39], demonstrating how the weakening of social institutions directly increases physical sensitivity.

While traditional crops provide a buffer, the system's overall sensitivity remains high. The reliance on wheat as a strategic crop increases food security sensitivity to water shortages. Furthermore, the exposure of critical infrastructure like the road connecting Suq Bayhan to Ataq to flooding can isolate the district, cutting off access to regional markets. Floods also pose a secondary health risk by contaminating water sources, potentially spreading diseases like cholera from flooded latrines into the water wells of low-lying communities.

5. Adaptive capacity

Bayhan possesses a strong historical foundation for adaptive capacity, rooted in its centuries-old traditional water management (sawaqi). The engineered structures like the Asr Dam and the Qaid Al-Awsat diversion spur represent a highly evolved form of adaptation. This inherent capacity is being bolstered by international projects. The FAO supports adaptive practices through drought-resistant seeds (e.g., Ghunaimy wheat), and the WFP enhances physical infrastructure through cash-for-work projects, such as those rehabilitating the Bir Lahmar water harvesting system.

However, this capacity is under severe strain. The primary challenge is fragility and degraded governance. Weak state institutions have resulted in a lack of comprehensive climate plans. Crucially, the erosion of the traditions that managed systems like the Jarban network has degraded the socio-institutional core of its adaptive capacity. Furthermore, ongoing conflict leads to the neglect of infrastructure; for instance, a damaged gabion wall on a main canal can render entire sub-systems like the Qatnah canal network ineffective. Therefore, while the technical knowledge for adaptation exists, the current socio-political context severely limits its application.

6. Climate Hazards Assessment

Table 4: Climate Hazards Assessment of Bayhan district

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Drought is a frequent, chronic stressor. Flash floods are less frequent but recurrent; major events every few years (e.g., 1996) cause catastrophic damage, while smaller events occur more often.	Prioritize interventions towards flood protection	10%

[39] Documented study, Traditional Irrigation Systems and Methods of Water Harvesting in Hadramout and Shabwah Governorate, 1996, EPA, Aden University (Netherland, MetaMeta)

2.	**Severity of Impact**	Drought has a severe, chronic impact on livelihood. Floods have a severe, acute impact on infrastructure and land. The 1996 flood event caused long-term damage to the wadi's morphology and agricultural base..	The flood and drought have similar impacts but different target areas	25%
3.	**Population Exposed to the Hazard**	A very high percentage of the population is exposed. Settlements and livelihoods are concentrated in the Wadi Bayhan floor (e.g., Suq Bayhan, Al-Ain). Their assets are directly in the hazard zone.	Target interventions to protect the largest number of people on and around Wadi Biahan	12%
4.	**Geographical Scope**	The impact is concentrated but absolute within the wadi system. The entire agricultural output of the district is confined to the Wadi Bayhan and its tributaries, leaving no alternative areas for production.	Target areas mostly Wadi Bayhan	3%
5.	**Impact on Water and Agricultural Resources**	This is the core vulnerability. The entire economy rests on the 7,500 hectares of cultivable land. Drought directly attacks the water supply (aquifer recharge). Floods attack the infrastructure (e.g., Asr Dam, Jarban canals) and the fertile soil itself.	Protect the wadi as one ecosystem	30%
6.	**Current Adaptive Capacity**	Capacity is strained. While traditional systems (sawaqi) show high historical adaptation, your scores show a current low adaptive capacity (score of 3 for drought, indicating low capacity). This is due to institutional fragility, degraded social contracts (traditions), and dependency on external projects.	Maintenance of existing water structure and support traditional adaptive capacity	15%
7.	**Presence of Vulnerable Groups in the Area**	Vulnerability is high among smallholder farmers and the poor. Reports indicate high poverty and unemployment in Shabwah. Food insecurity is at IPC Phase 2/3, making these groups highly sensitive to any climate shock.	Direct efforts towards protecting the smallholder farmers and the poor	5%

The severity of the two main hazards; flood and drought, followed by the crucial factor that the region's once-high adaptive capacity is now significantly weakened. The exposure of the population and the

frequency of events are significant but secondary factors compared to the fundamental reliance on and threat to the water-agriculture system.

ii. Markha Al-sofla Climate Change Vulnerability Assessment

1. Overview

Located within Shabwah Governorate, Markhah Al-Sofla is a district encompassing an area of 2,591 square kilometers[40], whose lifeblood and greatest vulnerability is its geography. The area is predominantly characterized by arid plains and valleys, with Wadi Khuwrah serving as the central topographical and socio-economic feature. This dry riverbed carves through the landscape, creating a basin of fertile soil that sustains the entire district.

The population is comprised largely of agrarian communities and pastoralists who cluster in and around the wadi. Their socio-economic existence is almost entirely tied to this fragile environment. The fertile land of Wadi Khuwrah supports the cultivation of successful crops like onions and potatoes, which are central to both local sustenance and trade. Livestock herding also provides a critical source of livelihood.

This direct dependence on the land makes Markhah Al-Sofla exceptionally vulnerable. The same wadi that provides fertile soil and seasonal water transforms into a torrential force during rains, subjecting the district to catastrophic flash floods that repeatedly devastate lives, farms, and infrastructure, creating a relentless cycle of loss and recovery for its inhabitants.

2. Major Hazards

Major hazards: table like this, just use it as a template for Markhah Al-sofla district

Table 5 Major hazards for Markhah Al-sofla district governorates can be summarized as follow:

Hazard & Risk	Ranking	Explanation & Context
Flash Floods	1	The district's defining vulnerability is flash flooding in Wadi Khuwrah. Major events in April 2020[41] and August 2025[42] each killed 5 people, displaced hundreds of families, and caused severe damage to roads, farmland, and water infrastructure, repeatedly isolating communities. This is the most immediate and catastrophic hazard.
Soil Erosion	2	Directly linked to the powerful flash floods in Wadi Khuwrah. The torrential waters wash away the fertile topsoil that is the foundation of

[40] Statistical Yearbook 2022, Central Statistical Organization - Yemen

[41] https://al-omana.net/news115491.html

[42] https://samaaden.news/archives/240736

		the district's agriculture, degrading farmland and threatening long-term food production and livelihoods.
Rain Variability	3	Irregular timing and intensity of rains disrupt planting cycles for key crops like onions and potatoes and are the primary driver of the devastating flash floods, creating a cycle of drought and flood.
Water Scarcity	4	Despite projects targeting water access, scarcity remains a critical issue. The flood damage to water sources highlight a system under stress. Scarcity is driven by damaged infrastructure, a lack of large-scale water harvesting to capture floodwater, and high dependence on variable rainfall.
Drought	5	Perceived as a lower immediate priority, than floods, but it is a chronic stress. Periods of low rainfall reduce water availability, impacting all sectors. The 2023 drought vulnerability assessment confirms significant exposure and low adaptive capacity.
Heat Waves	6	The immediate, life-threatening impact of floods places them as the paramount hazard. Heat waves undoubtedly stress crops, increase water evaporation, and pose health risks, compounding other water and agricultural stresses.
Water Salinity	7	This is a known stressor, likely exacerbated by over-extraction of groundwater to compensate for variable rainfall and damaged surface water sources.

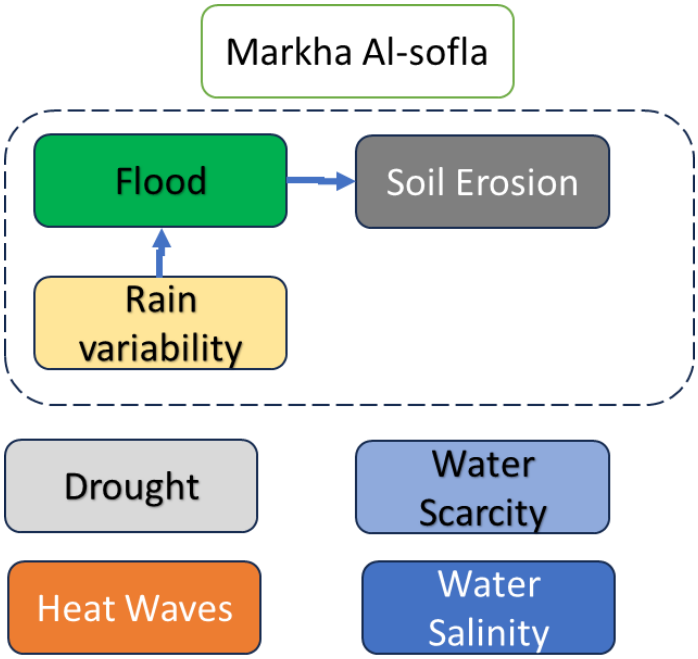


Figure 2: Markhah Al sofla climate change hazards/risks interlink, drought flood is the main climate change driver

3. Exposure

The population around 63,802 people[43] and assets of Markhah Al-Sofla are highly exposed to climate hazards, primarily concentrated in and around the basin of Wadi Khuwrah. This wadi is the lifeblood of the district, providing fertile land for agriculture (onions, potatoes) and the primary course for seasonal water. However, this also makes it a death trap during intense rainfall events. The repeated, catastrophic flooding demonstrates that entire communities, their homes, their farmland, and critical infrastructure like roads and water projects are directly in the path of destructive flash floods. The geographical confinement of habitable and fertile land to this wadi system means that a very high percentage of the population is exposed to its dual nature of sustenance and danger.

4. Sensitivity

The concentration of people and livelihoods in a single flood-prone wadi makes the district critically sensitive.

The entire agricultural economy of Markhah Al-Sofla is dependent on the fertile soils of Wadi Khuwrah. Flash floods that destroy onion and potato crops directly wipe out the primary source of income for a large portion of the population. Furthermore, the damage to roads isolates communities, cutting them off from markets and aid, while the destruction of water infrastructure—the very same projects documented as humanitarian responses—creates an immediate drinking water crisis, as seen in the 2020 and 2025 events. The impact of a single flood event is therefore multiplicative, devastating housing, livelihoods, and basic survival resources simultaneously.

[43] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

The recurring displacement and loss of life highlight extreme human sensitivity. The fact that two separate flood events five years apart resulted in identical death tolls (5 people each) and significant displacement (~100 families in 2020) indicates a population with high vulnerability living in hazardous conditions. Families are forced to rebuild in the same vulnerable locations due to a lack of alternatives, leading to a tragic cycle of loss. The drowning of individuals in vehicles and homes points to a lack of safe zones and early warning systems, leaving people highly exposed to the sudden onset of floods.

While humanitarian projects improve water security, they also create new sensitivities if damaged. The completed water projects from the Emirates Red Crescent in Old Al-Hawtah and Direct Aid in Al-Jarshah are lifelines for thousands of people. However, their location in the flood-prone district makes them sensitive assets. If these reservoirs and pumping units are damaged by a future flood, it would not only represent a financial loss but would also plunge the dependent populations into an even deeper water crisis, undoing years of development work and increasing their dependency on external aid.

5. Adaptive capacity

The adaptive capacity in Markhah Al-Sofla is low, characterized by a reactive rather than proactive approach. The community has shown resilience in repeatedly rebuilding after floods, but the cycle of disaster-response-disaster indicates a fundamental lack of capacity to mitigate the root cause of the shocks.

The presence of modern water projects from international NGOs demonstrates that external support is a key component of the district's adaptive capacity, providing a buffer against water scarcity. However, this capacity is fragmented and project-based, not systemic. The almost complete absence of **Disaster Risk Reduction (DRR)** infrastructure—such as flood walls, diversion channels, or community-wide early warning systems for Wadi Khuwrah—is the most significant adaptive capacity gap. The fact that floods continue to cause identical outcomes shows that adaptive measures have not kept pace with the climate threat.

Local capacity is further strained by poverty and isolation. The damage to roads limits access to markets, emergency services, and information, reducing the community's ability to prepare for or respond to hazards. The focus has necessarily been on immediate humanitarian relief (water, food) rather than long-term adaptive infrastructure, leaving the underlying vulnerabilities unaddressed and the population highly dependent on external actors for survival and recovery.

6. Climate Hazards Assessment

The table shows the hazards assessment against the specific criteria and the main necessary objectives

Table 6: Climate Hazards Assessment of Markhah Al-Sofla is a district

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Floods are a recurrent and documented hazard (2020, 2025). Drought is a chronic stressor, exacerbated when seasonal rains result in destructive floods rather than usable water.	Prioritize interventions against flood is priority	15%
2.	**Severity of Impact**	Flood impact is catastrophic and repeatable: loss of life, displacement of hundreds of families, destruction of critical infrastructure (roads, water sources), and erosion of agricultural land. The impact is severe and multifaceted.	The flood has a high impact. The drought is more link to water scarcity	25%
3.	**Population Exposed to the Hazard**	A large portion of the population lives and farms in the flood-prone basin of Wadi Khuwrah. The entire district is exposed to water scarcity following infrastructure damage.	Target interventions to protect the wadi system especially in wadi Khuwrah	20%
4.	**Geographical Scope**	Flash floods primarily impact the central Wadi Khuwrah corridor, which is also the location of most villages and agricultural land. This concentrates the risk on the district's core economic and population center.	Target areas mostly the wadies system with highest agriculture area	5%
5.	**Impact on Water and Agricultural Resources**	The economy is entirely dependent on climate-sensitive agriculture in the wadi. Floods destroy crops and erode the land itself. Damage to water infrastructure creates immediate scarcity. The impact on core resources is direct and devastating.	Protect the delta as one ecosystem	25%
6.	**Current Adaptive Capacity**	Capacity is very low. Recurrent disasters prove a lack of effective DRR measures. While water projects help, they are vulnerable to damage. Poverty and isolation limit self-funded	More focus on capacity of local government to plan the flood and drought management	7%

		adaptation. There is a critical gap in flood mitigation.		
7.	**Presence of Vulnerable Groups in the Area**	The recurring displacement creates groups of highly vulnerable people who are forced to live in hazardous conditions. Smallholder farmers are immediately pushed into crisis by flood damage to their crops and land.	Direct efforts towards protecting the most vulnerable livelihoods and breaking the cycle of displacement.	3%

Output

This assessment, mirroring the community's own ranking, unequivocally identifies Flash Floods as the paramount climate hazard requiring urgent and targeted intervention in Markhah Al-Sofla.

iii. Nisab Climate Change Vulnerability Assessment

1. Overview

Nisab District in northern Shabwa Governorate, Yemen, is a stark example of a region trapped in a triple crisis: protracted conflict, severe climate change impacts, and acute economic collapse. Its population of 65,900[44] people, spread across 2,150 square kilometers[45] relies on agriculture and livestock, but these livelihoods are being rapidly eroded by environmental degradation.

The district's diverse topography, featuring deserts, highlands, and critical valleys (wadis), makes it highly vulnerable to climate shocks. It suffers from a destructive cycle of recurrent droughts and intense flash floods, the latter often caused by weather events in neighboring governorates. These floods destroy vital irrigation systems, while droughts lead to crop failure, groundwater depletion, and livestock loss.

This environmental crisis is compounded by a critical water shortage due to failed infrastructure and a lack of reliable electricity to run water projects. Consequently, the district faces widespread food insecurity (classified as IPC Phase 3-Crisis, with some areas in Phase 4-Emergency), extremely limited access to basic services, and a low capacity for humanitarian response due to its remote location.

Despite these challenges, the report notes resilience, such as local-led projects building stone walls to manage floodwater for irrigation. The overarching conclusion is that climate change is a "threat multiplier," accelerating a humanitarian crisis in an already fragile context.

[44] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen
[45] Statistical Yearbook 2022, Central Statistical Organization - Yemen



Figure 3: Nisab district, settlement areas close to the main stream

2. Major Hazards

Table shows main hazards and its important, integrated from local community ranking and literature review

Table 7: Major hazards for Nisab district governorates can be summarized as follow:

Hazard & Risk	Ranking	Explanation & Context
Drought	1	Classified as one of the most drought-vulnerable districts. Prolonged conditions (2021-2023) cause significant crop failure, groundwater depletion, and livestock loss, directly eroding the agrarian economy.
Heat Waves	2	Increasing temperatures associated with the desert climate stress limited water resources, increase evaporation from critical water reservoirs, reduce livestock productivity, and pose direct health risks to the population.
Rain Variability	3	Irregular timing and intensity of rainfall, which primarily falls in summer and spring, disrupts planting cycles and reduces the reliability of both rain-fed and spate irrigation agriculture.

Water Scarcity	4	A central crisis exacerbated by climate change, failed infrastructure, and lack of electricity. The depletion of groundwater and interrupted water networks create a "stifling" crisis for both domestic use and irrigation
Soil Erosion	4	A central crisis exacerbated by climate change, failed infrastructure, and lack of electricity. The depletion of groundwater and interrupted water networks create a "stifling" crisis for both domestic use and irrigation
Water Salinity	5	While not the primary concern, over-extraction of groundwater due to drought and scarcity can lead to increasing salinity in wells, threatening both drinking water and crop health. Some communities mainly depend on water with high salinity
Flash Flood	6	While not the primary concern, over-extraction of groundwater due to drought and scarcity can lead to increasing salinity in wells, threatening both drinking water and crop health.

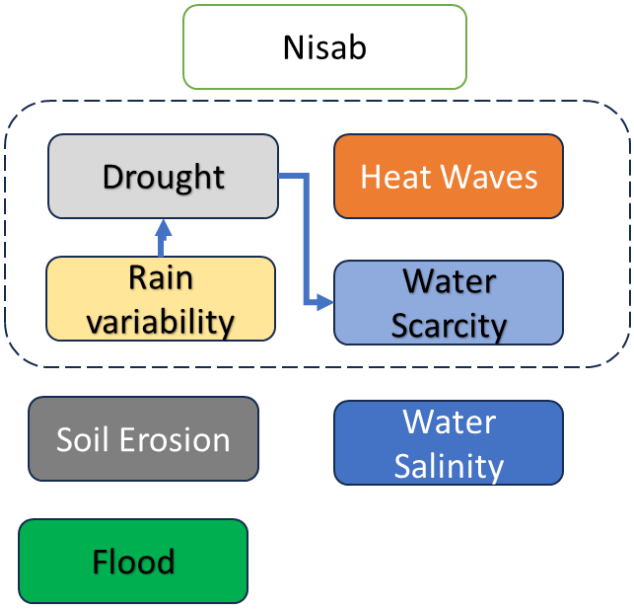


Figure 4: Nisab climate change hazards/risks interlink, rain variability and drought are the main climate change drivers

3. Exposure

The communities of Nisab are highly exposed to a range of interlinked climate hazards. The district's diverse topography dictates the nature of this exposure. Populations in the vast desert areas are primarily exposed to chronic drought and heat waves, which deplete water sources and threaten pastoral livelihoods.

Conversely, communities residing in and along the critical network of valleys (Wadis Dhraa, Abdan, Al-Hanak, Al-Hajar, Hamam) are directly exposed to destructive flash floods, particularly as the district is a catchment for floodwater from the upstream Hatib district of Abyan. This makes their homes, farms, and essential irrigation canals highly vulnerable[46]. The entire population of approximately 65,900 people is exposed to acute water scarcity due to systemic infrastructure failure and climate-induced drought.

4. Sensitivity

The high dependence of Nisab's population on climate-sensitive agrarian and pastoral livelihoods makes the entire socio-economic system profoundly sensitive. The district accounts for an estimated 30% of Shabwa's agricultural production, with key areas like Nisab, Abdan, Dhraa, and Al-Hanak heavily reliant on valley agriculture. Flash floods that destroy traditional spate irrigation canals immediately cripple farmers' ability to cultivate, leaving agriculture in "dire straits." Similarly, prolonged drought directly leads to crop failure and loss of livestock, which are primary sources of income and wealth. This sensitivity is exacerbated by the near-total absence of government services and alternative economic opportunities.

The reliance on crops like wheat, fodder, and vegetables, alongside beekeeping in Sidr tree areas, provides a baseline livelihood but remains highly sensitive to water availability. A significant portion of the workforce depends directly on these sectors, meaning water shortages or climate shocks create a ripple effect through the local economy, impacting traders and laborers in local markets.

Furthermore, the operational failure of basic services drastically increases sensitivity. The crippling lack of reliable electricity paralyzes water projects, meaning communities cannot respond to scarcity even when infrastructure exists. This dependency on broken systems leaves them acutely sensitive to any climate shock that further strains water availability, as seen in the public protests over water and electricity.

5. Adaptive capacity

The adaptive capacity of Nisab's communities is severely constrained by poverty, conflict, and a collapsed service infrastructure, yet demonstrates remarkable grassroots initiative. Government capacity is "virtually non-existent," with poorly equipped health clinics and schools, indicating a very low institutional capacity to support adaptation.

The chronic water crisis, compounded by a lack of electricity to run projects, highlights a critical limitation in technical and infrastructural capacity. Financial capacity is also low, as noted by the "high cost of restoration" for farmers after floods, which prevents them from cultivating their land.

However, adaptive capacity is not zero. Communities, sometimes with external support, are developing and implementing effective, context-specific solutions. The construction of stone walls in Al-Qaryatayn Valley is a prime example of building ecological infrastructure to simultaneously mitigate flood risk and harness

[46] Dar Alhikma news, Link

water for irrigation, a practice that has already shown promise for the upcoming season[47]. Projects like the distribution of efficient irrigation networks and the shift towards solar-powered water solutions (e.g., the Saqam project) are crucial steps toward building more sustainable, off-grid adaptive capacity[48]. These efforts show a practical knowledge of the local environment and a capacity to mobilize around effective solutions, even in the absence of state support.

6. Climate Hazards Assessment

Table summarized the main criteria for climate hazards assessment and its explanation according to the Nisab district situation, and highlighting the main objectives to be prioritized.

Table 8: the main criteria for climate hazards assessment and its explanation according to the Nisab district situation

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Drought: A chronic, multi-year stressor. The period 2021-2023 was marked by prolonged drought conditions (Dar Al-Hikma), indicating it is a near-constant threat. Floods: Recurrent seasonal events triggered by upstream rainfall in Hatib, Abyan. Documented events in 2016 (Ma'araba) and ongoing mitigation projects (Al-Qaryatayn, 2023) confirm regular occurrence.	Prioritize interventions primely against drought and secondary flood	10%
2.	**Severity of Impact**	Drought: Impact is economically catastrophic, leading to crop failure, groundwater depletion, and livestock loss. This drives the district into IPC Phase 3 (Crisis) and Phase 4 (Emergency)[49]. Floods: Impact is immediately catastrophic and lethal (deaths in Ma'araba, 2016)[50]. They destroy vital spate irrigation canals in Wadi Dhraa, Abdan, etc., crippling agriculture.	The drought has a high impact, especially in overall livelihood. The flood has impacts but when big events occur	25%
3.	**Population Exposed to the Hazard**	Drought: Effectively the entire population of 65,900 is exposed to its effects on water availability, food prices, and livelihood loss. Floods: Populations in the critical valleys (Dhraa, Abdan, Al-Hanak, Al-Hajar, Hamam)	More focus on drought impacted population	15%

[47] Social fund for development (SFD), Link
[48] Aden Gate news, Link
[49] IPCinfo, Link
[50] Saba news 2016, Link

		are directly exposed. These are the most populous and productive areas.		
4.	**Geographical Scope**	Drought: Impacts the entire district, from the deserts to the highlands. Floods: Impacts are concentrated but critical, focused on the valley systems that contain the most fertile land and settlement. Destroying these areas has an outsized impact on the entire district's food output	To focus efforts on the city of Nisab as highest economic value area and areas in the wadies	5%
5.	**Impact on Water and Agricultural Resources**	This is the paramount criterion for Nisab. The district is a significant agricultural producer (30% of Shabwa's production). The economy is entirely dependent on climate-sensitive sectors. Drought: Directly attacks the core resources: depleting groundwater and killing crops. Floods: Destroys the infrastructure (canals) but also represents a lost opportunity for water harvesting.	Area with high drought, providing water for people and agriculture is the main focus, use of flash flood should be integrated	30%
6.	**Current Adaptive Capacity**	Drought: Capacity is very low. The "stifling water crisis" and reliance on broken, electricity-dependent networks (Al-Awsha protest) show a system unable to cope[51]. Floods: Capacity is low but emerging. The community-led construction of stone walls in Al-Qaryatayn Valley (2023) shows a practical, effective adaptive response that improves resilience.	Drought still the most hazard that community can't cope with	10%
7.	**Presence of Vulnerable Groups in the Area**	Vulnerability is high across groups: Smallholder Farmers in Abdan, Dhraa who cannot repair canals. Pastoralists in desert areas who lose livestock. The Urban Poor in Nisab city facing a "stifling water crisis". Residents of Flood-Prone Wadis like Ma'araba.	Direct efforts towards protecting the most vulnerable groups	5%

[51] Al-omana news, Link

The assessment prioritizes climate hazards based on their threat to Nisab's survival, which is anchored in its agricultural and water resources. The district's role as a significant agricultural producer for Shabwa makes the impact on water and land the most critical factor.

The severe consequences of hazards, measured in human lives lost to floods and widespread famine from drought, are the next priority. The vast number of people exposed—essentially the entire population to drought and major communities in the wadis to floods—further justifies a high-level response.

While the constant recurrence of these shocks and the community's low capacity to cope are important for designing solutions, they are secondary to the immediate, catastrophic impact on essential resources. Targeting specific locations and vulnerable groups is a final, tactical consideration within this broader strategic framework.

iv. Radhum Climate Change Vulnerability Assessment

1. Overview

Located on the shores of the Arabian Sea in southeastern Yemen, the Radhum (Rudum) district in Shabwah governorate is a vast and storied coastal territory stretching over a 280-kilometer strip, covering an area of 6,680 square kilometers[52], famed for its natural beauty and economic significance. Its topography is a dramatic blend of arid coastal plains, lush agricultural pockets like the La'arif area with its over 2,000 palm trees[53], and remarkable geological formations such as the sulfuric Lake Shoran in Bir Ali. While precise population figures are challenging to confirm estimates suggest a population of approximately 36,545 people[54], its communities are sustained by a fragile water system reliant on natural springs like the therapeutic Rudum Hot Springs and seasonal floods, which are increasingly threatened by crisis and erosion. The way of income for its people is deeply tied to this environment, resting on two pillars: agriculture, where date palms, mangoes, and olives are cultivated, and the sea, which supports vital fishing grounds and hosts critical infrastructure like the Port of Qana and the Nashima Oil Terminal. Despite this potential, the district's agriculture remains vulnerable, a stark contrast to its immense but often untapped resource wealth.

[52] Statistical Yearbook 2022, Central Statistical Organization - Yemen

[53] Yemen news, Link

[54] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

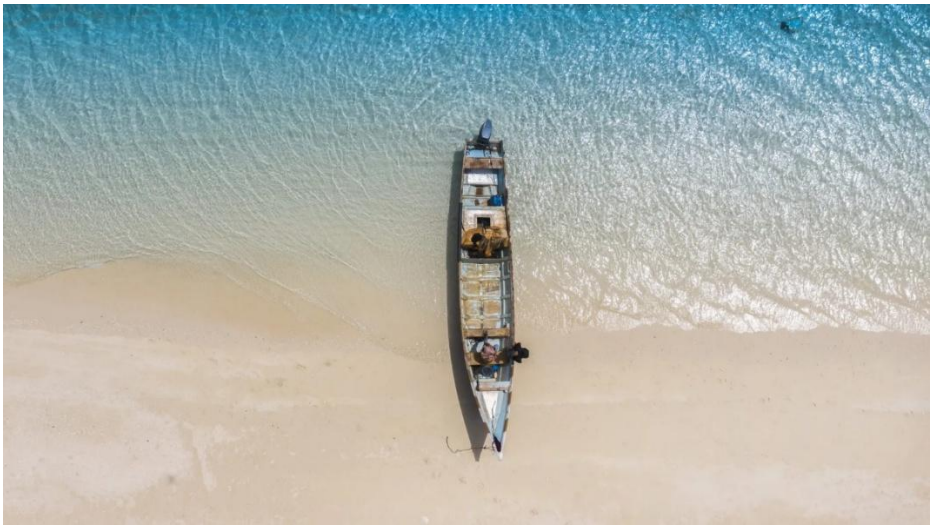


Figure 5: Fishing in Radhum is on of the most important community income

2. Major Hazards

The table highlight the main climate hazards; the ranking is developed from the local community during the field work and from literature review

Table 9: Major hazards for Radhum district governorates can be summarized as follow:

Hazard & Risk	Ranking	Explanation & Context
Flash Floods	1	The district's topography, featuring wadis like Wadi Bana, is highly prone to destructive flash floods following intense rainfall. Historical events, like the cyclones in 2015 (Chapala)[55] and major flooding in 2020 and 2024, demonstrate their devastating impact, eroding agricultural land, destroying homes (e.g., in Jil'ah)[56], damaging critical infrastructure like bridges and water projects (e.g., in Hura), and washing topsoil to the sea[57].
Water Salinity	2	Intrusion of saline water into coastal aquifers due to sea-level rise, storm surges, and over-extraction of groundwater threatens both agricultural productivity (e.g., palm groves) and drinking water sources in coastal areas like Al Khobar and Bir Ali.

[55] Shabwah press, Link
[56] ibid
[57] Aljadeed press, Link

Soil Erosion	3	Directly linked to flash floods and unsustainable land management. The loss of fertile topsoil from wadi beds and agricultural areas degrades potential, reduces yields, and threatens long-term food production.
Drought	4	Its chronic nature is a severe stressor. Periods of low rainfall (e.g., the 2025 drought) reduce water availability in wells and springs (e.g., the dried-up Mashhara springs), directly impacting agriculture, leaving palm groves barren, and threatening livestock and livelihoods[58]. Its ranking may reflect a higher immediate fear of sudden floods over slow-onset disasters.
Water Scarcity	5	A growing concern due to the combination of physical scarcity from drought, inefficient water use, lack of storage infrastructure (leading floodwater to be lost to the sea), and salinity contamination. This affects year-round irrigation and domestic use.
Rain Variability	6	Irregular timing, intensity, and distribution of rains (a change from traditional patterns) disrupt planting cycles, reduce the reliability of rain-fed agriculture, and paradoxically intensify flood risk when intense, short bursts of rain occur.
Heat Waves	7	Perceived as a lower immediate priority, but increasing frequency and intensity of heat waves stress crops, reduce livestock productivity, increase water evaporation from soil and surface sources, and pose direct health risks to a population with limited access to cooling or healthcare

[58] Almahriah TV 2025, Link, also Direct observation by the project team during the field visit

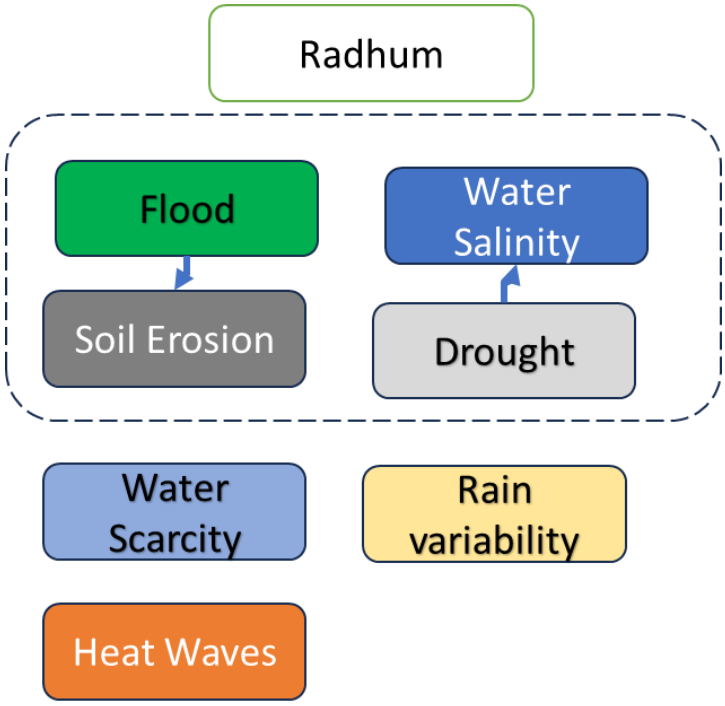


Figure 6: Radhum climate change hazards/risks interlink, flood and drought are the main climate change drivers

3. Exposure

The population and assets of Radhum are highly exposed to multiple climate hazards. The entire coastal strip, including towns like Al Khobar, Bir Ali, and Balhaf, is exposed to sea-level rise, salinity intrusion, and cyclonic storm surges. Inland, the communities residing in and around the Wadi Mayfaah basin are directly exposed to flash flooding. Agricultural areas dependent on seasonal springs, like the La'arif palm plantations, are exposed to drought and water scarcity. Critical infrastructure, including the Nashima Oil Terminal, the Balhaf LNG facility, and the international coastal highway, is located in exposed zones, making it vulnerable to flooding and extreme weather events.

4. Sensitivity

The high importance of exposed infrastructure and ecosystems for livelihoods makes the system very sensitive.

The coastal and agricultural communities are highly dependent on the fertile wadi beds and the marine resources of the Arabian Sea. A flash flood that erodes topsoil in Wadi Bana or a cyclone that damages the fishing boats in Al Khobar directly destroys the primary source of income for these villages. Furthermore, the disruption of the coastal highway or key economic infrastructure like the oil terminal by a flood would sever critical transport and economic links, paralyzing the local economy.

The presence of vulnerable groups, including potentially Internally Displaced Persons (IDPs) who may have settled in hazardous locations, drastically increases sensitivity to loss and damage. Communities residing in informal settlements on the outskirts of towns or on vulnerable low-lying land are often living in the most fragile housing. A flood event in these areas, like the one that submerged Jil'ah in 2024, would

have a disproportionate human impact, as these groups have minimal safety nets and limited capacity to recover.

The reliance on drought-resistant crops (e.g., sorghum, millet, dates) and fishing is a positive factor (lower sensitivity to drought for some). However, a significant portion of the workforce depends directly on these climate-sensitive sectors. When the Mashhara springs run dry or the fishing season is bad due to cyclones, it is not just farmers and fishermen who suffer. The entire local economy—from date traders to boat mechanics—feels the impact because a large percentage of the population derives its income directly or indirectly from these sectors, with few alternative sources of revenue.

5. Adaptive capacity

The adaptive capacity in Radhum is critically low. Poverty, isolation, and ongoing conflict are fundamental constraints. The suspension of the major Balhaf LNG project, which could have provided economic diversification and resources, has left the district without a crucial buffer. The repeated damage to infrastructure, such as the destruction of the Hura water project's solar panels in 2024, demonstrates a cycle of loss and inadequate recovery that depletes community resources[59].

There is a severe lack of climate-resilient infrastructure. The absence of effective water harvesting structures, sea walls, early warning systems, or reinforced riverbanks means communities are repeatedly exposed to shocks with minimal protection. Traditional water sharing systems, like those for the Rudum Hot Springs, show inherent adaptive knowledge, but they are being overwhelmed by the scale of current challenges like severe drought and flooding.

Institutional support is weak, and financial assistance for adaptation is sporadic and insufficient to address the systemic vulnerabilities. This combination of factors leaves the communities of Radhum highly vulnerable to climate shocks with a very limited capacity to adapt or recover autonomously.

6. Climate Hazards Assessment

The table shows assessment of climate changes hazards, their background information and the main necessary objectives

Table 10: Climate Hazards Assessment of Radhum district

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Radhum is exposed to cyclones from the Arabian Sea and erratic rainfall. Cyclone Chapala (Nov 2015), major floods (Mar 2020, Mar 2024).	Prioritize interventions that make livelihoods	10%

[59] Aljadeed press 2024, Link

		Climate models project increased intensity of rainfall events.	resilience to frequent floods and cyclones	
2.	**Severity of Impact**	The destructiveness and irreversible damage caused by a single event or ongoing stress, such as the March 2020,[60] and 2024 flood in Jil'ah destroyed over 100 homes, displacing 1,100+ residents and requiring a disaster declaration[61].	The flood has a high impact. The drought has impacts on the coastal areas	25%
3.	**Population Exposed to the Hazard**	The hazard's impact on human life, health, and displacement. The March 2024 flood in Jil'ah displaced over 1,100 residents and destroyed 100+ homes. The Mar 2020 floods caused loss of life and livestock.	Target interventions to protect the largest number of people on the main settlements in Radhum	10%
4.	**Geographical Scope**	The value and extent of assets and areas exposed. The entire coastal strip (280 km) and Wadi Radhum basin are exposed. Key towns: Jil'ah, Bir Ali. Critical infrastructure: Balhaf LNG, Nashima Oil Terminal, coastal highway.	Target areas mostly the strategic infrastructure in the coastal area	15%
5.	**Impact on Water and Agricultural Resources**	Effect on primary economic sectors: agriculture (dates, mangoes, sesame) and fishing. Floods in Wadies erode topsoil. The 2025 drought left date palms barren. The Hura windstorm (Aug 2024) destroyed the water project, crippling the community.	Protect the main crops and fishery	20%
6.	**Current Adaptive Capacity**	Community's ability to cope based on resources, knowledge, and institutional support. Very Low. data Conflict has suspended the Balhaf LNG project, eliminating jobs. Lack of early	Prioritize addressing flood and in some coastal areas water crisis due to water scarcity and salinity	15%

[60] Adngad news 2020, Link
[61] Shabwah press 2024, Link

		warning systems, resilient housing, or water management infrastructure		
7.	**Presence of Vulnerable Groups in the Area**	Exposure of populations with high sensitivity and low capacity to cope, including IDPs, poor farmers, and marginalized communities. IDPs settled in Radhum from other conflicts. Fishing communities in Al Khobar, smallholder farmers in La'arif, and residents of remote mountain villages.	Direct efforts towards protecting the most vulnerable groups such as low-income farmers and fishermen	15%

Radhum District faces a dual climate threat, but drought poses the greater long-term danger. While flash floods are more immediately violent and traumatic—destroying homes and infrastructure in an instant—drought is the silent, systemic crisis. It slowly strangles the district's lifeblood by drying up critical water sources like the Mashhara springs, withering the date palms of La'arif, and pushing the agricultural and pastoral systems that most people depend on toward collapse. Ultimately, the relentless scarcity of water represents the most profound existential threat to Radhum's future.

2..2 Climate change vulnerability Abyan governorate

2..2.1 Climate and Socio-Economic Profile Abyan Governorate

Socioeconomic Context

Abyan, a Yemeni governorate spanning approximately 16,943 km² with an estimated population of 619 thousand[62], features a diverse topography of coastal plains, mid-elevation mountains, and highlands. Its economy is predominantly reliant on agriculture in the fertile Abyan Delta, livestock rearing, and fishing along its 300 km coastline, which serves as a primary source of income and protein for coastal communities. This is supplemented by local trading and some industries, including cement and manufacturing. However, this economic potential is severely undermined by the impacts of climate change—resulting in a severe water scarcity crisis and destructive floods—which lock the population into a cycle of poverty and vulnerability. This situation is drastically worsened by prolonged conflict and political instability, which have displaced tens of thousands and crippled development.

Abyan's climate is fundamentally hot and arid, transitioning to semi-arid conditions inland towards the Bana catchment. This environment is characterized by low and highly unreliable rainfall, intense sunshine, and high levels of solar radiation. A defining feature is the high temporal and spatial variability of precipitation. The governorate experiences two distinct rainy seasons: a primary one from July to September, driven by the southwesterly monsoon, and a secondary period from March to May, influenced by the Red Sea Convergence Zone (RSCZ) where cooler Mediterranean air converges with warmer flows.

[62] Statistical Yearbook 2022, Central Statistical Organization - Yemen

Despite these periods, the annual average rainfall is only about 235 mm, with significant variation across districts, ranging from 50 mm in coastal Ahwar to 350 mm in higher elevation areas like Sarar[63]. This scarcity is exacerbated by extremely high potential evapotranspiration, estimated at 1,795 mm per year, creating a severe water deficit.

Climate Change Profile

Climate change scenarios (past and future), for main climate change indicators for Abyan governorate, based on some available reports[64].

Table 11: Climate change scenarios (past and future), for main climate change indicators for Abyan governorate

Climate Indicator	Past Observation	Future Projection
Avg. Temp	Part of the southern coastal zone. Likely experienced warming similar to Aden (+0.75°C/decade).	Projected increases of +3.5 to +4.0°C (coastal zone projection).
Tmax	Located in a zone of significant increase. Estimated increase of +0.03 to +0.04°C/yr (~+1.1 to +1.4°C total 1981-2016)	Projected to follow the Arabian Sea coastline trend of severe increase
Precipitation	Lies in a low-rainfall zone (<150mm/yr). Likely experienced a slight, statistically insignificant decrease seasonal rains.	High uncertainty. Could see a slight decrease or increase, but with higher variability
Very Warm Days (≥35°C	High baseline (100+ days/yr). Experienced an increase of +0.6 to +1.0 days/yr and reach to +1.4	One of the governorates with the highest projected increase: +80 to +100 additional days/year
Sea Level Rise	*Historical rate of ~3.3 mm/year observed in Aden. Saltwater intrusion already extends ~4km inland in the Abyan delta*	For the Gulf of Aden coast: projected rise of 0.3-0.6m by 2100, Projected to accelerate to 5.9 mm/year or more under high-emission scenarios

[63] Derek et all 2018, simulating water allocation and cropping decisions in Yemen's Abyan Delta Spate Irrigation System, Water

[64] Climate risk Country Profile WB 2023, Climate Impact Potential Assessment Yemen EPA FAO GCF 2023, Country Climate and Development Report CCDR 2024 WB

Key Risks	*Coastal erosion, sea-level rise, cyclone landfall, extreme heat stress on agriculture and population*	Increased cyclone intensity, severe water scarcity due to higher evaporation, salinization of coastal aquifers.

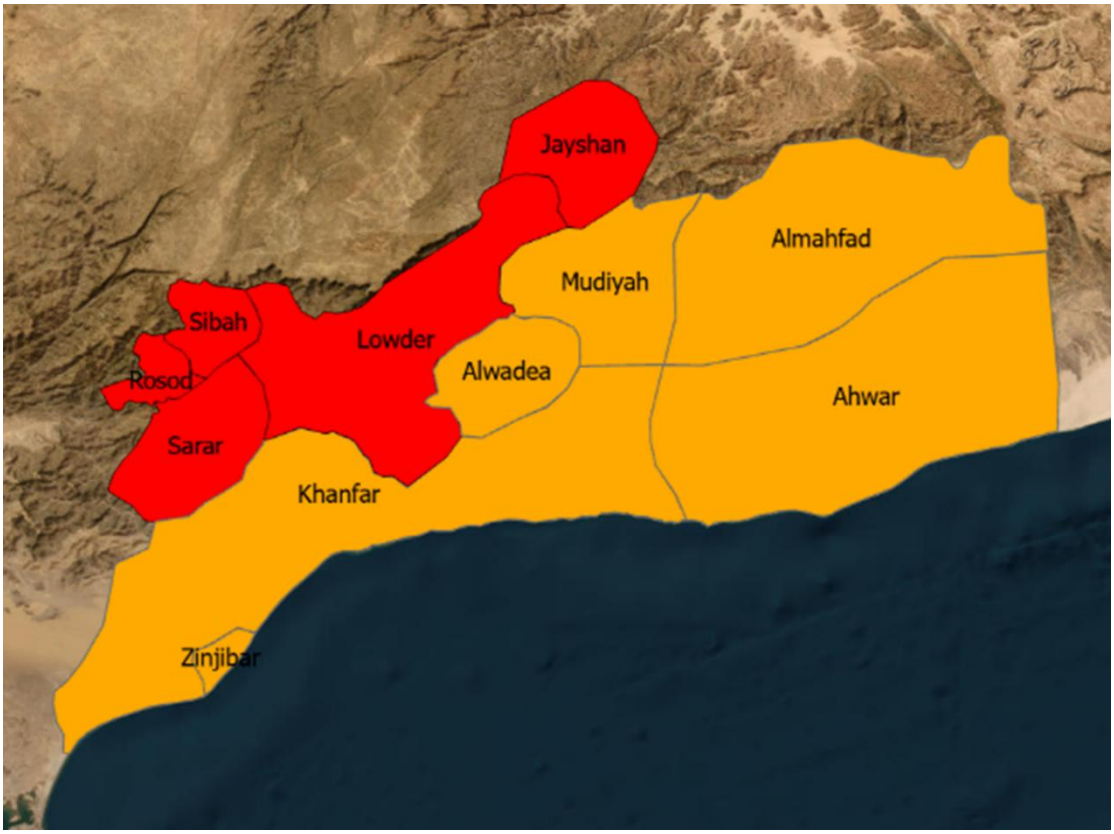
Dominant Agro-Ecological Zone: Arabian Sea Coastline

Temperatures show strong seasonal and diurnal patterns, moderated near the coast by the sea. The coastal plains, including Zinjibar and Khanfar, experience hot summers with average maximum temperatures between 35°C and 43°C and warmer winters. In contrast, the inland plateaus have a greater range, with warm summers and cold winters where minimum temperatures can drop to between 9°C and 12°C. The region is also subject to gusty winds from June to August, which frequently lead to dust storms and reduced visibility, compounding the challenges of the arid climate.

Overall Vulnerability Narrative

The socio-economic context of Abyan is deeply intertwined with its climate and compounded by protracted conflict. With a population of approximately 619,000, nearly half of whom are women, the governorate's economy is overwhelmingly dependent on agriculture and fishing. This reliance makes the population acutely vulnerable to climate variability and water scarcity. The sector has been devastated by conflict, which has destroyed critical irrigation infrastructure in the agriculturally vital Abyan Delta. This has led to a paradoxical situation where seasonal floodwaters are poorly managed—causing erosion and damaging homes, roads, and bridges—while the bulk of the water is lost to the sea, failing to irrigate crops effectively. This destruction, combined with a nearly 50% loss of agricultural workers and severely weakened purchasing power, has crippled livelihoods.

Consequently, water scarcity is extreme, with availability in Yemen as low as 150 m^3 per capita per year, making conflicts over this scarce resource common; water disputes have been linked to over 100 deaths in the Abyan Delta over the past decade. Despite its high agricultural potential, these factors have driven profound poverty, with rural poverty rates historically at 50.44%, a figure that has undoubtedly worsened due to the conflict, currency depreciation, and soaring commodity prices. The deterioration of living conditions fuels civil unrest, exposing the population to heightened protection risks and severe food insecurity, creating a cycle of vulnerability where environmental stress and socio-economic fragility continuously reinforce each other.



Map 5: Climate change vulnerability to drought (Red: high risk, Dark Yellow: Middle), from climate change vulnerability Assessment to district level for four selected Yemeni governorates (EPA, FAO, 2024)

Table 12 : Abyan's districts Hazard & Risk Ranking by priorities (from literatre and consultation)

District	Drought	Flood	Water scarcity	Water salinity	Heat waves	Soil erosion	Rain variability
Sarar	1	5	2	7	6	4	3
Lowder	1	6	5	7	4	3	2
Almahfad	4	6	3	7	5	1	2
Ahwar	7	1	5	3	4	2	6

This analysis reveals highly localized environmental priorities, demanding distinct adaptation interventions for each district. Ahwar's foremost challenge is flooding, making investment in stormwater management

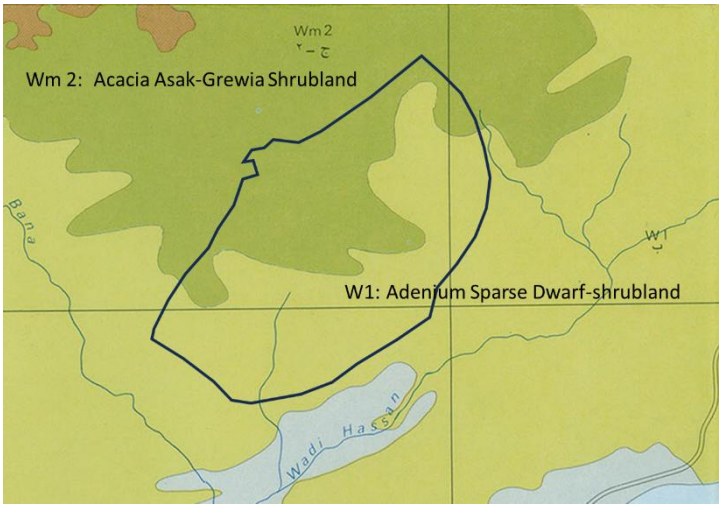
systems, flood-resistant infrastructure, and early warning networks its critical adaptation path. In contrast, Sarar and Lowder must prioritize addressing drought through interventions focused on water conservation, drought-resistant crops, and the expansion of efficient irrigation techniques like drip systems. Meanwhile, Almahfad's top priority is soil erosion, requiring immediate actions such as contour farming, reforestation projects, and the construction of terraces and check dams to stabilize the land and protect vital soil resources.

District-level climate change vulnerability assessments

i. 1.Sarar Climate Change Vulnerability Assessment

1. Overview

Sarar district, which is one of the districts located in the areas with mountainous terrain stationed in the north & northwest of Abyan Governorate, where these areas are characterized by the abundance of high mountains in them. The area of Sarar is 746 square kilometers[65], and has a total population of 22,185[66]. Jabal al-Hamr (2044 m) and Jabal Al-Bada (1952 m), Jabal Manwar (1699 m), and Jabal Masud (1288 m) are all in Sarar district. Wadi Hattat also passes through the Sarar district, and it is one of the most important valleys in Abyan Governorate.



Map 6: Sarar district main vegetations, Al-khuleidi et all, 1990, Environmental Protection Council (EPC) - Yemen

The main livelihoods activity in Sarar district are; the government jobs, work for daily wages, livestock, and immigration. The agriculture deteriorated significantly in Sarar district because of, from time to time, many areas and villages of the district are exposed to severe drought, which causes the destruction of crops and animals and the displacement of many people to other places in search of about water, as well as the lack of dams and public rainwater harvesting tanks, and complete absence of support for the agricultural

[65] Statistical Yearbook 2022, Central Statistical Organization - Yemen

[66] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

sector and farmers in the district8. Sarar district have lower access to piped water supply, there is water shortage, and low access to sanitation (multi-sectoral)

2. Major hazards

This table prioritizes the hazards based on their current and projected impact on the district, as derived from the literature review and community participation through field work:

Table 13: Major hazards for Sarar district governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Drought	1	A chronic and devastating hazard. Major events occurred in 2010, 2016, 2018, 2019, 2022, and 2024. It directly causes water scarcity, displacement, agricultural failure, and the collapse of livelihoods (livestock, bees, crops), leading to widespread humanitarian crises.
Water scarcity	2	Directly linked to and a primary consequence of drought. The drying of springs and wells, combined with difficult terrain that prevents water truck access and the lack of water storage infrastructure, makes this a daily struggle for survival, not just an agricultural issue.
Rain variability	3	The problem is not just low rainfall, but its increasing unpredictability in timing, intensity, and distribution. This disrupts planting cycles for rain-fed agriculture on terraces and makes traditional water harvesting methods unreliable
Soil erosion	4	When rain does fall, it often comes intensely on barren, mountainous terrain, with several streams. Without vegetation or dams to slow runoff, topsoil is quickly washed away into deep valleys, further degrading the limited arable land on terraces.
Flash floods	5	Although the main characteristic of Sarar is drought but flooding events in 2020 and 2025. Intense, variable rainfall on steep slopes leads to destructive flash floods that can wipe out terraces, damage infrastructure, and ironically, waste precious rainwater by rushing it to the sea.
Heat waves	6	Increasing temperatures exacerbate evaporation from the few remaining water sources, increase water needs for humans and livestock, stress already vulnerable crops, and contribute to the desiccation of vegetation, worsening the overall aridity. The heat increased towards the south.

Water salinity	7	While likely a lesser issue in highland aquifers compared to coastal areas, over-extraction of groundwater during droughts can lead to a concentration of minerals and salts in wells, reducing water quality for drinking and irrigation

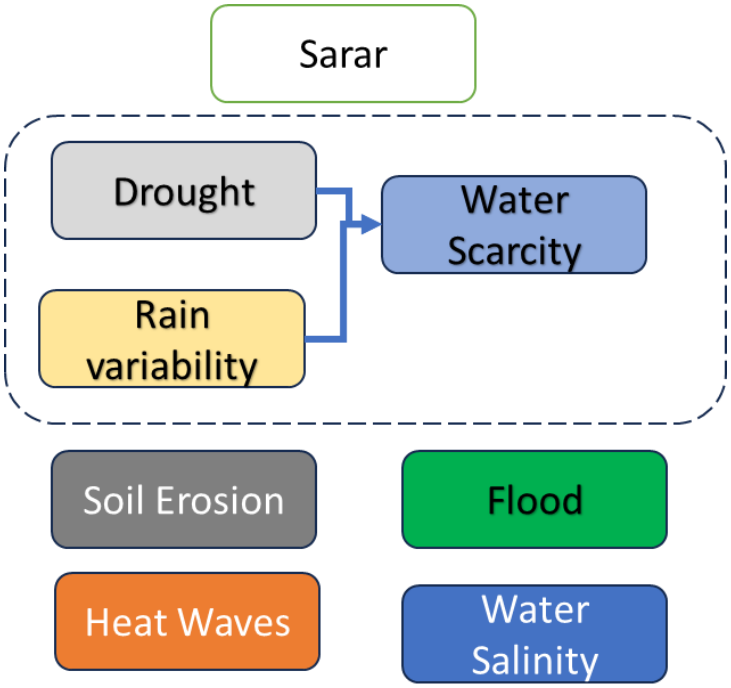


Figure 7: Sarar climate change hazards/risks interlink, rain variability and drought are the main climate change drivers

3. Exposure

The entire population of Sarar district is highly **exposed** to climate hazards due to its geographic and socio-economic conditions. The district's mountainous terrain means villages are exposed to landslides and rapid runoff during heavy rain, while their elevation and distance from reliable water sources expose them acutely to drought. The primary assets exposed are the city of Sarar with health facilities especially the city is located in the wadi's connections, the scattered agricultural terraces, sorghum yields dropped by 55% from 2015 to 2023, livestock, the banks of seasonal valleys (where the most productive land is found), traditional water reservoirs, and the homes of residents which are often simple structures vulnerable to both prolonged dry spells (cracking) and flash floods. The Google Earth imagery confirming the drying of trees and terraces since 2010 is direct evidence of this long-term exposure.

4. Sensitivity

Heavey resilience on agriculture with limited water

The sensitivity of Sarar district is critically high, primarily due to an almost total reliance on climate-sensitive livelihoods. The population's sensitivity is extreme because their primary sources of income—rain-fed terrace agriculture, livestock rearing, and beekeeping—are directly destroyed by drought. The drying of springs and wells doesn't just impact farming; it triggers a chain reaction of sensitivity across all sectors. Families must spend a disproportionate amount of their limited income on purchasing water at inflated prices, leaving less for food, healthcare, and education. This economic sensitivity is compounded by the difficult terrain, which makes the physical delivery of aid and water by trucks expensive and sometimes impossible, further isolating communities.



Figure 8: Wadi Sarar, agriculture eon the valley banks

5. Migration due to climate changes

The displacement crisis is both a result of and a factor increasing sensitivity. Those who have been forced to move to new areas often live in tents or rented housing with no safety net. They have lost their productive assets (farms, beehives) and are now entirely dependent on external assistance, making them profoundly sensitive to any additional shock, whether a price increase in basic goods or a disease outbreak. The closure of schools in drought-beaten areas indicates a societal-level sensitivity, where a generation's education is sacrificed due to climate impacts, reducing long-term adaptive capacity.

6. Adaptive capacity

The adaptive capacity in Sarar district is currently very low.

Adaptation to drought

The community's traditional adaptation methods, such as building small cement tanks on rooftops for rainwater harvesting, are failing due to the low and unpredictable rainfall, leaving these tanks empty. While there is evidence of individual effort and some intervention by international organizations to build and restore water storage facilities (dams, cement tanks, barriers), these are described as needing maintenance and are insufficient to meet the scale of the problem.

The district's poverty, compounded by recurring droughts, means financial resources to invest in larger-scale adaptations (e.g., building large dams, implementing drip irrigation, drilling deep wells) are nonexistent for most individuals and likely strained at the district level. The difficult mountainous terrain is a natural barrier to adaptation, making large infrastructure projects challenging and costly. The mass displacement itself is a tragic indicator of failed adaptation; when communities can no longer cope, they are forced to abandon their homes and livelihoods. This suggests a breakdown of their existing coping strategies and a urgent need for external support to build resilient water infrastructure and diversify livelihood options.

Adapting to flood

Despite the dry climate of Sarar District, flash floods do occur, but there is no clear strategy for adapting to these sudden events. To date, there are limited local efforts to maintain the terraces, but there is no plan for storage of floodwaters.

Impacts Assessment framework

Assessment of climate change impacts for Sarar district. The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 14: Assessment of climate change impacts for Sarar district

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Drought is a frequent and chronic hazard (2010, 2016, 2018, 2019, 2022, 2024). Water scarcity is a constant stress. Flash floods, while less frequent, are recurrent (2020, 2025).	Prioritize interventions against the drought as the main hazard	20 %
2.	**Severity of Impact**	Impact is catastrophic: loss of life and livelihoods, forced displacement, collapse of entire village economies, and closure of schools. It destroys the social fabric.	Drought causes the most profound and wide-ranging human suffering and lead to migration.	30 %
3.	**Population Exposed to the Hazard**	Nearly the entire population is exposed to drought and water scarcity due to the reliance on rain-fed agriculture and mountain springs. Remote villages are most exposed	Target interventions that protect the largest number of people, particularly in dispersed mountain villages.	15 %

4.	**Geographical Scope**	Drought and water scarcity are widespread across the entire mountainous district. Flash floods are more localized to valleys and watersheds.	Address the hazard that affects the broadest geographical area and the most villages.	10 %
5.	**Impact on Water and Agricultural Resources**	Drought directly causes the failure of the three main livelihood pillars: crops, livestock, and bees. It is the root cause of water scarcity.	Protect and enhance the primary water supply and water for agricultural resources upon which all life in the district depends.	15 %
6.	**Current Adaptive Capacity**	Capacity is very low. Poverty, geographic isolation, and lack of large-scale water storage infrastructure (dams) mean communities are overwhelmed. Traditional methods are failing.	Water scarcity is the main hazard the community is least able to cope with on its own, so focusing on technical and financial support for water infrastructure.	5%
7.	**Presence of Vulnerable Groups in the Area**	Vulnerability is extremely high. This includes displaced populations living in tents, residents of remote villages cut off from aid, and those who remain in dried-up villages with no alternatives.	Farmers in the villages are most vulnerable groups, they have already lost everything and have no capacity to recover.	5%

This assessment, clearly identifies Drought and the resulting Water Scarcity as the paramount climate hazards facing Sarar District. Any climate adaptation strategy for Sarar must first and foremost address the critical need for sustainable water capture and storage to break the cycle of drought leading to displacement and collapse



Map7 : Map: The impacts of drought between 2010 and 2024 (google earth, 2025)

ii. Lowder Climate Change Vulnerability Assessment

1. Overview

Located in the central highlands of Abyan Governorate, Yemen, Lowder (Lawdar) District is a region of significant agricultural importance and stark environmental challenges, and is home to an estimated 130,699 inhabitants[67]. It is one of the largest districts in the governorate by area, with a total size of 2,166 square kilometers[68], characterized by a diverse and elevated terrain ranging from 1,100 to 2,000 meters above sea level.

The district's climate is predominantly arid and semi-arid, featuring hot summers, mild winters, and critically, scant and irregular rainfall. This climate supports a rich biodiversity, including over 243 plant species, and a thriving agrarian economy known for producing tomatoes, grains, fruits, and high-quality livestock.

However, Lowder faces a severe and persistent water crisis, exacerbated by climate change impacts like drought, heatwaves, and unpredictable heavy rains, which continually threaten its water security and agricultural livelihood.

2. Major hazards

Fieldwork results, discussion with communities and authorities and desktop review of available literatures provide an important approach for categorizing climate change hazards, ranking hazards as follows: **(1 is the highest).**

Table 15: Major hazards for Lowder district governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Drought	1	A severe, chronic stressor exacerbated by a major heatwave in 2011 that dried up groundwater wells. This leads to livestock death, agricultural damage, and desertification, directly threatening the primary livelihoods in this arid/semi-arid district.
Rain Variability	2	Characterized by "scant and irregular rainfall." This unpredictability disrupts planting cycles for the district's diverse crops (grains, vegetables, fruits, tomatoes) and reduces the reliability of rain-fed agriculture, which is critical for a predominantly farming community.

[67] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen
[68] Statistical Yearbook 2022, Central Statistical Organization - Yemen

Soil erosion	3	Caused by heavy, irregular rains on varied terrain. This degrades the agricultural land that is the district's economic backbone, reducing yields and long-term productivity.
Heat Waves	4	Increase evaporation, stress crops, reduce livestock productivity, and exacerbate water scarcity, as seen in 2011.
Water Scarcity	5	A critical issue. Caused by drought, over-extraction, and inefficient use. The text notes a "severe shortage of potable water" and that "several areas continue to suffer from water scarcity and significantly higher prices for water transported by truck.
Flood	6	Exposure to "heavy rains, especially in recent years (2023 and 2025), in addition to the 2020 floods." The varied terrain (high to medium altitude) makes certain areas prone to flash floods during these intense rainfall events.
Water Salinity	7	A growing concern linked to over-extraction of groundwater. As water tables drop, the potential for salinity concentration and intrusion increases, threatening both irrigation for high-value crops like tomatoes and drinking water.

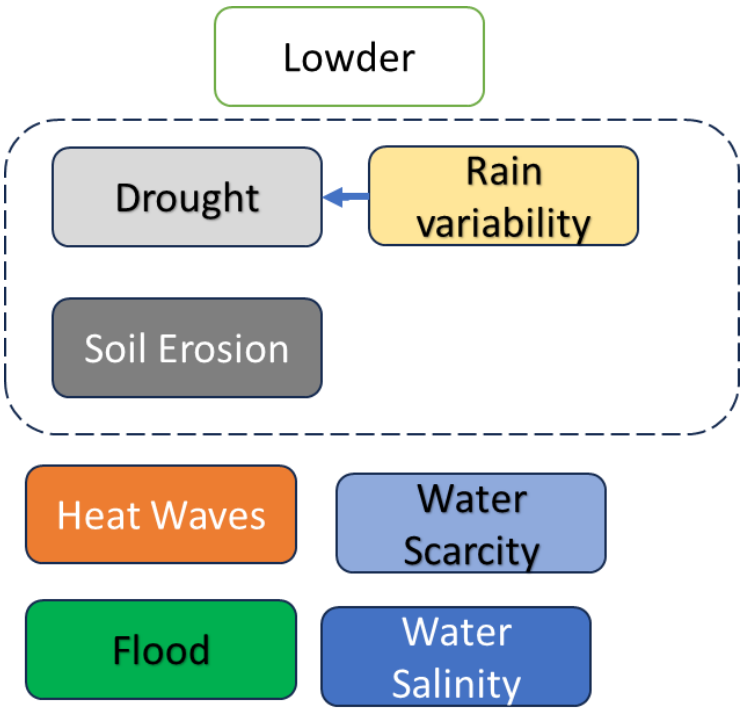


Figure 9: Lowder climate change hazards/risks interlink, rain variability and drought are the main climate change drivers

3. Exposure

The entire district is exposed to the primary hazard of drought and rainfall variability due to its arid nature. The exposure is not uniform due to the diverse terrain. Populations in lower-lying valleys and basins are exposed to flash flooding during periods of intense rain (e.g., 2020, 2023, 2025).

Agricultural lands, spanning over 1,100 to 2,000 meters in altitude, are widely exposed to heat stress and water scarcity. Critical infrastructure, like the new Lawdar Water Project wells and networks, is exposed to the changing climate conditions that affect groundwater recharge. The district's rich biodiversity, with over 243 plant species, is also exposed to these shifting climate patterns.

4. Sensitivity

The high dependence on climate-sensitive agriculture and livestock makes the district profoundly sensitive. The economy is almost entirely agrarian, with the cultivation of tomatoes, grains, fruits, and cotton, and a strong livestock sector (sheep and goats). Any disruption to water availability or temperature patterns directly destroys the primary source of income for a large percentage of the population. The 2011 crisis demonstrated this high sensitivity, where water scarcity led directly to the death of livestock and damage to agricultural production.

The phenomenon of steep tomato price drops during the season highlights a key sensitivity: a lack of diversified economic options and value-added processing (e.g., canning factories). This lack of market resilience means climate-induced gluts directly translate to significant financial losses for farmers, with no buffer.

While the presence of Internally Displaced Persons (IDPs) is not explicitly detailed, the general reliance on agriculture suggests that smallholder farmers are highly vulnerable. A bad season due to drought or erratic rains leaves them with no safety net and limited capacity to recover, as their entire livelihood is threatened.

The ongoing water crisis, despite projects like the Lawdar Water Project, indicates that sensitivity to water scarcity remains critically high. Communities still reliant on expensive water trucking are acutely sensitive to price shocks and interruptions in supply.

5. Adaptive capacity

Adaptive capacity for drought

Adaptive capacity is emerging but remains insufficient to meet the scale of the challenge. There are clear and positive efforts to build resilience. The recent Lawdar Water Project (drilling four artesian wells, building tanks, and a 30km network) is a significant infrastructural investment directly aimed at adapting to water scarcity. Similarly, the existence of other projects like the Al-Mahaith Water Project, water barriers, and valley maintenance shows a institutional and community understanding of the need for water harvesting and management.

External assistance programs, such as the distribution of livestock (sheep/goats) and improved seeds (sesame, millet, sorghum), are crucial for building adaptive capacity. These actions help diversify and strengthen livelihoods against climate shocks. The promotion of drip irrigation networks is a critical step towards improving water-use efficiency, a key adaptive strategy in arid regions.

However, adaptive capacity is limited by significant challenges. The continued suffering from water scarcity and high prices indicates that these projects have not yet reached all areas or solved the underlying water deficit. The lack of tomato canning factories points to a gap in economic adaptation, leaving farmers exposed to market gluts. Overall capacity is constrained by the district's economic profile, and the success of adaptive measures is still partial and unevenly distributed across the population.

6. Impacts Assessment framework

Assessment of climate change impacts for Lowder district. The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 16: Assessment of climate change impacts for Lowder district

	Criterion	Definition	Objective	Weight
1)	**Frequency of Occurrence**	The arid climate and scant rain make drought a perpetual concern, with acute crises like 2011, but also heavy rain events are irregular but notable in recent years (2020, 2023, 2025).	Drought is highly occurring especially its impacts on water scarcity with grow population of Lowder	15 %
2)	**Severity of Impact**	Directly causes well failure, death of livestock, collapse of agricultural production (e.g., tomatoes, grains), and accelerates desertification.	The drought has a high impact, especially in areas with high population density like in the Lowder city	30 %
3)	**Population Exposed to the Hazard**	The entire population and the dominant agrarian economy are exposed to water scarcity. The tomato crisis shows high economic sensitivity, Populations in the district's valleys and basins are exposed. Key economic assets (farms, water projects) in these areas are at risk.	Target interventions to protect the largest number of people on the city of Lowder and surrounding.	20 %
4)	**Geographical Scope**	Impacts all areas, from the highest altitude regions down to the valleys.	Target areas mostly the Lowder valley	5%

5)	**Impact on Water and Agricultural Resources**	The economy is entirely dependent on climate-sensitive sectors, agriculture and water, the drought impacted them and directly affected the livelihoods.	Marketing, new drought resilience crop varieties and re-use of waste and grey water especially in the big settlements	20 %
6)	**Current Adaptive Capacity**	Significant projects exist (Lawdar Water Project, drip irrigation), yet a "severe shortage" persists, indicating capacity is still overmatched, limited flood protection projects	Strengthening planning and data collection, for better decision making	5%
7)	**Presence of Vulnerable Groups in the Area**	Smallholder farmers, pastoralists, the poor and IDPs are entirely dependent on climate-sensitive resources and have few alternatives when drought strikes.	Design interventions that will directly or indirectly strengthening these groups	5%

Lowder district can be a demonstration area for moving from pure disaster response to a more proactive approach of managing environmental risks, the district has a good knowledgeable people, administration, core projects and close to decision making power in Aden. Water management is critical issue, while there is water availability and some water projects but still water scarcity is the main issue.

iii. Almahfad Climate Change Vulnerability Assessment

1. Overview

Almahfad District is a rural region of 2,256 square kilometers[69], within Yemen's Abyan Governorate, defined by a complex interplay of environmental potential and profound socio-economic challenges. The population which estimated to be 39,406 people[70], resides in villages scattered across mountainous terrain and along extensive valley networks, with livelihoods predominantly reliant on climate-sensitive activities. The community is primarily agrarian, engaged in rain-fed and groundwater-irrigated agriculture and pastoralism, producing key crops such as grains (wheat, corn), sesame, vegetables—notably tomatoes—and citrus fruits. Beekeeping, especially in areas like Bakazem, serves as a critical source of income and nutritional diversity, representing a high-value yet highly climate-vulnerable sector. Agriculture and livestock sales constitute the primary sources of income, with limited non-agricultural economic activity indicated by quarries for cement and building stone.

While specific district-level poverty data is scarce, the broader context of Abyan Governorate—one of Yemen's poorest regions—combined with the devastating eight-year national conflict, provides a clear picture. The conflict has decimated infrastructure, collapsed governance systems, and severely eroded community resilience. This chronic national crisis fundamentally undermines the socio-economic foundation, exacerbating poverty and crippling innate adaptive capacity—a vulnerability intensified by the

[69] Statistical Yearbook 2022, Central Statistical Organization - Yemen
[70] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

presence of Internally Displaced Persons (IDPs) and other vulnerable groups. Despite possessing significant groundwater reserves extracted from depths of 70-90 meters, this potential is threatened by over-exploitation via random well drilling, a lack of management, and climatic shocks. Although drinking water projects exist, many remain incomplete or non-functional, leading to critical access issues exemplified by villages such as Marei, thereby compounding the district's vulnerability.

2. Major hazards

This table prioritizes the hazards based on the local community's ranking and the contextual information provided.

Table 17 :Major hazards for Almahfad district governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Soil Erosion	1	Directly linked to frequent and intense flash floods. The 2023 floods demonstrated this, causing severe soil erosion that damaged agricultural lands and roadsides. The topography, with many valleys (e.g., Wadi Al-Khadira, Wadi Al-Hamra), accelerates runoff. The invasive Mesquite trees *Prosopis juliflora* exacerbate the problem by blocking flood channels, increasing water force and erosion. Loss of fertile topsoil directly degrades the district's primary economic asset—its agricultural land.
Rain Variability	2	Irregular timing, intensity, and distribution of rains are a critical underlying driver. Unexpected heavy rains cause floods, while unreliable patterns disrupt planting cycles for key crops like tomatoes, grains, and sesame. This variability reduces the reliability of both rain-fed and valley-recharge agriculture, creating a cycle of flood and water scarcity crises.
Water Scarcity	3	A paradox of flooding and scarcity. Despite seasonal rains, the district struggles with year-round water access. The 2021 and 2023 floods flow away unused, recharging aquifers insufficiently. Incomplete or poorly maintained water projects and random well drilling indicate systemic water stress. Villages like Marei face acute difficulty accessing water, impacting both domestic use and irrigation.
Drought	4	Periods of low rainfall reduce surface water and lower groundwater tables. With water already extracted from 70-90m depths, this indicates a stressed aquifer. Drought reduces yields for the widespread crops (sesame, corn, citrus) and threatens livestock and the important beekeeping industry in areas like Bakazem.
Heat Weaves	5	Increasing temperatures stress water resources through evaporation, directly impact key crops like tomatoes and citrus, reduce livestock

		productivity, and pose health risks to a population with limited access to cooling infrastructure. Heat waves compound the effects of water scarcity.
Flood	6	Its impact is catastrophic and recurrent (2021, 2023). Flash floods through the many valleys cause deaths, destroy homes, erode soil, and damage critical infrastructure like roads and bridges. The high ranking may reflect community adaptation to its recurrence, but its severity is extreme.
Water Salinity	7	No mention in the literature, it may be a future or localized threat rather than a current district-wide priority. Over-extraction from aquifers could potentially lead to salinity issues, but current data suggests other hazards are more pressing.

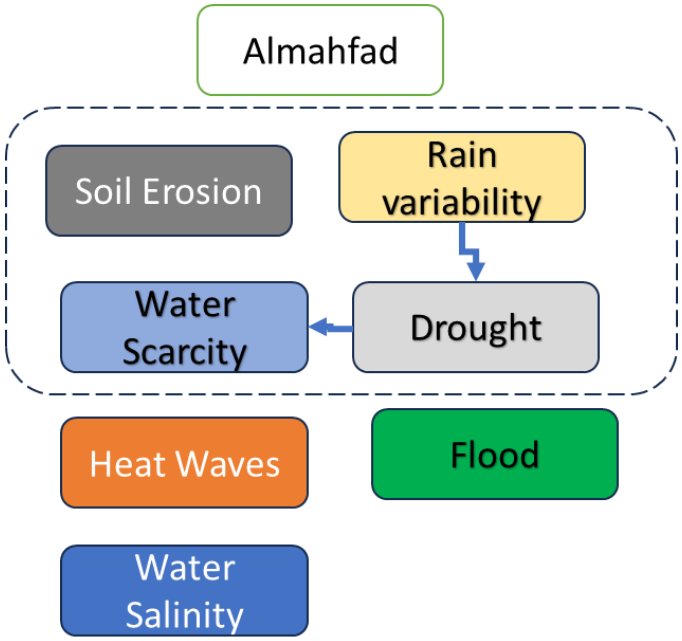


Figure 10: Almahfad climate change hazards/risks interlink, Rain variability and drought are the main climate change drivers

3. Exposure

Exposure to drought

The population and assets of Al-Mahfad are highly exposed to climate hazards due to their geographic distribution and economic base. The district's defining feature—its vast network of valleys (wadis) including Wadi Al-Khadira, Wadi Al-Hamra, and Wadi Rafd—is both its lifeline and its greatest threat. Agricultural areas (20,000 acres, with only 5,000 cultivated) and numerous villages are situated directly in

and around these valley basins, placing them directly in the path of flash floods. Critical infrastructure, including roads and bridges, is also exposed, as evidenced by their damage in the 2023 floods.

Exposure to flood

Furthermore, the scattered nature of villages across mountains, while potentially reducing flood exposure for some, increases their exposure to drought and water scarcity due to isolation and difficulty in establishing centralized water networks.

4. Sensitivity

High dependency on agriculture

The high dependence on climate-sensitive agriculture and livestock makes Al-Mahfad's socio-economic system extremely sensitive. The drowning of seven girls from one family in the 2021 floods tragically underscores the human sensitivity to flash floods, particularly for those living in vulnerable, low-lying areas near valleys. The economy is fundamentally sensitive; damage to agricultural crops (like tomatoes), livestock, and bees from events like the 2023 floods directly destroys the primary source of income for a significant portion of the population. This impact ripples through the local economy, affecting traders and laborers.

Invasive species

The presence of invasive Mesquite trees *Prosopis juliflora* is a key sensitivity multiplier. By invading agricultural areas and blocking flood channels, they directly compete with crops for water (increasing sensitivity to scarcity) and worsen flood damage and erosion (increasing sensitivity to floods). The reliance on crops like sesame, millet, and sorghum is a positive factor indicating lower sensitivity to drought, as these crops are more resilient to water stress. However, the cultivation of water-intensive crops like tomatoes and citrus increases sensitivity in those specific areas.

Infrastructure fragility

Sensitivity is further heightened by infrastructural fragility. The damage to citizens' homes and the erosion of roadsides during floods indicate construction that cannot withstand climate shocks. The fact that many water projects are incomplete or in need of maintenance leaves communities sensitive to the next drought or flood, as their adaptive systems are non-operational.

5. Adaptive capacity

The adaptive capacity of Al-Mahfad District to its primary climate hazards—drought and floods—is **fragmented and critically low**. While the community possesses inherent resilience and there are attempts at structured intervention, the overall ability to anticipate, absorb, and recover from shocks is severely hampered by systemic failures and a lack of resources.

Adaptive Capacity to Drought and Water Scarcity:

The district's approach to drought is a mix of traditional practices, individual initiatives, and failed projects, leaving it highly vulnerable. On a positive note, farmers exhibit a degree of adaptation by cultivating drought-resistant crops like sesame, sorghum, and millet, which provides a crucial buffer during dry spells. Furthermore, the knowledge from previous studies indicating good water reserves at 70-90 meters depth has led to widespread individual action, most notably **random well drilling**. However, this is a maladaptive practice that threatens the long-term sustainability of the aquifer and benefits only those with the financial means to drill.

The institutional adaptive capacity is where the system breaks down. **The failure to complete and maintain water projects is the single greatest weakness.** Drinking water projects and planned irrigation rehabilitations that remain unfinished represent a massive gap between planning and execution. This leaves communities, especially scattered villages like Marei, exposed. The planned water harvesting tanks and barriers that remain unbuilt represent lost opportunities to capture floodwater for use during dry periods, perpetuating the cycle of flood-induced scarcity. Consequently, the district's ability to manage its water resources efficiently and equitably is very low, making it highly susceptible to prolonged drought.

Adaptive Capacity to Floods:

The community's capacity to cope with floods is even more dire. The tragic loss of life, as seen in 2021, is the most stark indicator of a lack of basic early warning systems and evacuation plans. The physical infrastructure is also highly vulnerable, with roadsides and bridges easily eroded and homes damaged, indicating construction that cannot withstand flood forces.

Critically, a major factor exacerbating flood damage is the proliferation of invasive Mesquite trees *Prosopis juliflora*, which block flood channels. The fact that this known hazard has not been systematically managed points to a significant failure in natural resource management and risk reduction, further reducing adaptive capacity.

While there are projects aimed at protecting valleys and lands from erosion, their incomplete status means they provide no actual protection when floods occur. The community is therefore left to react to floods rather than prepare for them. The response is primarily *reactive* (post-flood recovery and rebuilding) rather than *proactive* (watershed management, early warnings, reinforced infrastructure). This lack of investment in preparedness results in a repetitive cycle of damage and loss, from which recovery becomes increasingly difficult, eroding the community's economic resilience with each new event.

In essence, Al-Mahfad possesses the knowledge of its problems but lacks the coordinated action, financial resources, and institutional follow-through to build effective resilience. Adaptive strategies are largely individualistic, uncoordinated, and in some cases harmful in the long term, while public projects stall at the implementation phase, leaving the district acutely exposed to climate shocks.

6. Impacts Assessment framework

Assessment of climate change impacts for Almahfad district. The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 18: Assessment of climate change impacts for Almahfad district.

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Flood events are recurrent, as evidenced in 2021 and 2023. The dense network of valleys (e.g., Wadi Al-Khadira, Wadi Al-Hamra) ensures flash floods are a regular threat during rains. Periods of inadequate rain are common.	The district shows mix of flood and drought, so flood storage is one of the potential solutions	15 %
2.	**Severity of Impact**	Flood cause direct loss of life (e.g., seven girls in 2021), destruction of homes and infrastructure (roads, bridges), total destruction of seasonal crops (e.g., tomatoes), and irreversible soil erosion, on the other side drought leads to crop failure, loss of livestock and bees (critical for areas like Bakazem),	Both flood and drought have high impacts but flood is more visible	30 %
3.	**Population Exposed to the Hazard**	Many villages are "scattered near valleys," placing them directly in flood pathways. The district center is also likely exposed. The majority of population is exposed. Agriculture-dependent families and remote villages (e.g., Marei) with poor water access are disproportionately affected.	Selection the interventions depends on needs; short survey is needed, because the communities live in scattered village and their needs are different	10 %
4.	**Geographical Scope**	Impacts are concentrated along the networks of wadis, which are the primary zones for agriculture and settlement. Drought affects all areas, from the district center to the most remote mountain village.	Distribute the intervention depends on the cause and survey	5%
5.	**Impact on Water and Agricultural Resources**	Flood directly destroys crops ready for harvest and degrades the land itself through topsoil erosion, reducing long-term fertility and productivity. Drought threatens the key income for locals such as beekeepers by reducing floral sources.	Target interventions to protect the more vulnerable people such as small holder farmers and beekeepers and other non-timber forest products collectors	25 %

6.	**Current Adaptive Capacity**	This is a critical vulnerability. Incomplete water projects and lack of maintenance leave no buffer against hazards. Maladaptive practices like random well drilling worsen scarcity. Mesquite trees Prosopis juliflora block channels, increasing flood risk. .	Focusing on existing water infrastructure and scale up traditional agriculture practices with modern knowledge	10 %
7.	**Presence of Vulnerable Groups in the Area**	Vulnerable groups include: smallholder farmers with no income diversification, residents of remote, mountainous villages with limited access to aid or services, families living in fragile housing near valley beds and beekeepers whose livelihoods are climate-sensitive.	Direct efforts towards protecting the most vulnerable groups	5%

In Al-Mahfad, the hazards of flood and drought are not separate issues but are intrinsically linked through water management failure. The district's low adaptive capacity is the thread that ties them together, a lack of water harvesting infrastructure (e.g., incomplete barriers and tanks), this water is not captured. This directly exacerbates the chronic drought and water scarcity (high impact on agriculture). There is agricultural potential, with avialbel land and un utilized water for irrigation. The community's practice of drilling deep wells (70-90m) is a direct, costly, and unsustainable adaptation to this scarcity. Therefore, the number one intervention to build resilience must focus on integrated water resource management—specifically, constructing and maintaining structures that capture floodwater to mitigate flood damage while simultaneously providing a water reserve to combat drought.

iv. Ahwar Climate Change Vulnerability Assessment

1. Overview

Ahwar district is strategically located between Shuqra and Wadi Mayfa'a, encompassing a vast area of 4,384 square kilometers[71]. The district occupies a leading economic position within Abyan Governorate due to its significant agricultural, fishing, livestock, and bee wealth, boasting one of the largest agricultural areas in the region.[2] This activity is primarily concentrated in the fertile basin of Wadi Ahwar, which produces key crops such as dates, grains (sorghum, millet), and sesame.[3] Animal husbandry (goats, cattle, camels) and beekeeping are integral to the local economy and a critical source of resilience.[4] A small marina supports a traditional fishing sector, further contributing to local food security and income. The district classified as IPC phase 5 emergency by IPCinfo.org[72].

[71] Statistical Yearbook 2022, Central Statistical Organization - Yemen
[72] https://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1159662/?iso3=YEM

The district is home to an estimated population of 37,494 people[73], though this figure may be outdated due to displacement caused by the protracted national conflict.[6] The population is dispersed across numerous small towns and villages, including the district capital (Ahwar Market), Al-Bahbah, Khumour, Al-Mahsama, and Ruwais.[7] Housing is predominantly traditional, constructed from mud, which inherently increases the population's physical vulnerability to climatic hazards, particularly flooding.

This vulnerability is exacerbated by the environmental context. Ahwar is an area of high rainfall, which frequently leads to destructive flash floods. These torrents have significantly altered the landscape, notably expanding the Wadi Ahwar basin from 750 meters to over 1,250 meters wide during a major event in 1996[74]. Paradoxically, despite this water abundance, the district recently suffers from severe drought in dozens of areas as torrential waters flow directly to the sea without being harvested for agricultural benefit.

The overarching national conflict has devastated infrastructure, crippled public services, and plunged a large majority of the population into poverty. Communities in Ahwar are highly sensitive to shocks due to their heavy reliance on climate-sensitive sectors, limited access to robust infrastructure (including paved roads and irrigation systems), and the presence of Internally Displaced Persons (IDPs) and other conflict-affected groups who have limited assets and coping capacity.

2. Major hazards

Fieldwork results, discussion with communities and authorities and desktop review of available literatures provide a crucial bottom-up perspective, ranking hazards as follows: **(1 is the highest)**

Table 19: Major hazards for Ahwar district governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Flash Floods	1	The topography of Wadi Ahwar makes it highly prone to destructive flash floods. Historical events, like the major flood in 1996 that widened the wadi to 1250 meters from 750m, demonstrate their devastating impact, eroding agricultural land, damaging mud-brick homes, and washing topsoil and crops to the sea
Soil Erosion	2	Directly linked to flash floods and changing rainfall patterns. The loss of fertile topsoil degrades agricultural potential, reduces yields, and threatens long-term food production.
Water Salinity	3	Intrusion of saline water into coastal aquifers due to sea-level rise and over-extraction of groundwater for irrigation threatens both agricultural productivity and drinking water sources.

[73] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen
[74] Ali Bin gunaid, 2014 "The Lower Basin, Wadi Ahwar and its Delta: A Geomorphological Study" Aden University

Heat Waves	4	Increasing frequency and intensity of heat waves stress crops, reduce livestock productivity, increase water evaporation, and pose direct health risks to the population
Water Scarcity	5	Despite seasonal rains, water availability for year-round irrigation and domestic use is a growing concern due to inefficient use, lack of storage, and salinity.
Rain Variability	5	Irregular timing, intensity, and distribution of rains disrupt planting cycles, reduce the reliability of rain-fed agriculture, and can paradoxically intensify flood risk.
Drought	7	Perceived as a lower immediate priority than floods, but remains a chronic stress. Periods of low rainfall reduce water availability in wells and surface sources, impacting all sectors

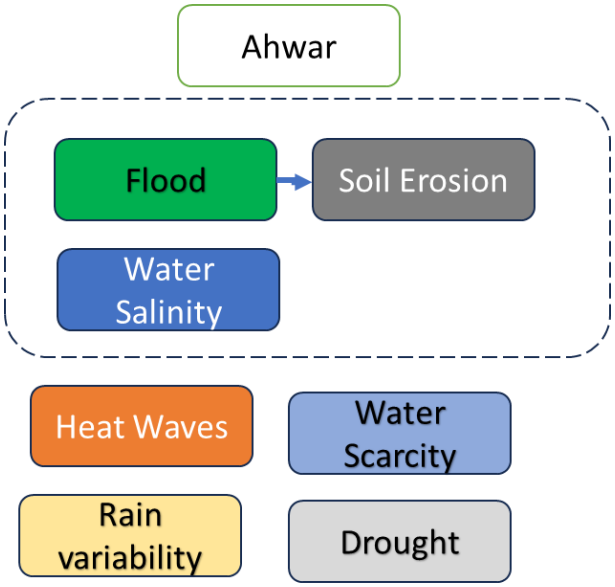


Figure 11: Ahwar climate change hazards/risks interlink, flood is the main climate change driver

3. Exposure

The communities and ecosystems of Ahwar District face significant exposure to both flooding and drought, threatening its core socio-economic and environmental assets.

Exposure to Flooding:

Ahwar's population exhibits a high degree of exposure to flood hazards. A significant portion of its nearly 100,000 inhabitants reside within flood-prone zones, particularly along the fertile Wadi banks and low-lying coastal areas. The district's ecosystems are highly exposed; the vital Wadi ecosystem and sensitive coastal mangroves are directly in the path of floodwaters, risking severe degradation. While the number of major infrastructures is limited (fewer than five), their exposure is rated as moderate to high due to the critical nature of the assets located in floodplains, such as the central marina, main market, and key transportation corridors, the disruption of which would severely impact the local economy and connectivity.

Exposure to Drought and Water Scarcity:

Exposure to drought and water scarcity is uniformly high across key sectors. The district's water resources, estimated at over 50 million cubic meters (MCM), are highly exposed to the dual threats of climate variability and over-extraction, making them inherently vulnerable to depletion. A large population, reliant on these resources for domestic use and livelihood activities, is consequently highly exposed to shortages. Furthermore, a significant agricultural area (less than 2,500 hectares) dedicated to water-dependent crops is highly exposed to variations in water availability, directly threatening local food security and the agrarian economy

4. Sensitivity

The high importance of exposed infrastructure and ecosystems for livelihoods makes the system very sensitive.

The Al-Bahbah and Khumour areas are highly dependent on the fertile lands of Wadi Ahwar for cultivating dates and grains. Flash floods that erode this topsoil directly destroy the primary source of income for these villages. Furthermore, the disruption of the Ahwar Market (the district capital) or the Ruwais marina by a flood would sever the critical economic links for selling agricultural goods, fish, and honey, paralyzing the local economy.

The presence of IDPs and other vulnerable groups, often living in the most hazardous locations, drastically increases sensitivity to loss and damage.

Internally Displaced Persons (IDPs), likely residing in informal settlements on the outskirts of Ahwar Market or on vulnerable low-lying land near the wadi, often live in the most fragile mud-brick housing. A flood event in these areas would have a disproportionate human impact, as seen in the tragic drowning of seven girls from one family in a similar district. These groups have no safety net and limited capacity to recover.

The reliance on crops with low water consumption (e.g., sorghum, millet, sesame) is a positive factor (low sensitivity).

Farmers in villages like Al-Mahsama and Al-Ja'ash who cultivate drought-resistant crops like sesame and sorghum are inherently less sensitive to periods of water scarcity compared to those who might try to cultivate water-intensive crops, providing a buffer during dry spells.

However, a significant portion of the workforce (>25%) still depends on agriculture, making the local economy highly sensitive to water shortages. When the wells in Village of Al-Malha run dry or the rains fail, it is not just farmers who suffer. The entire local economy—from traders in Ahwar Market to transporters—feels the impact because such a large percentage of the population in these communities derives its income directly or indirectly from agriculture, leaving no alternative sources of revenue.

The phenomenon of "severe drought" in dozens of farms in Wadi Ahwar, despite seasonal rains, is a direct consequence of this overstressed system. The aquifer is already being mined, meaning that a slight reduction in rainfall or an increase in temperature (increasing evaporation) will immediately lead to well failures in villages like Marei, threatening both drinking water and the irrigation that supports the date groves.

5. Adaptive capacity

The ability of Ahwar's communities to adjust to and manage climate hazards is constrained by significant financial and institutional weaknesses, despite the presence of some positive factors.

Adaptive Capacity to Floods:

The district's capacity to adapt to destructive flash floods is critically low. While communities possess traditional knowledge of seasonal weather patterns, this is insufficient against increasingly unpredictable and intense rainfall. Formal early warning systems are weak or non-existent, leaving villages like Al-Mahsama and Khumour, situated directly along the Wadi Ahwar basin, with minimal time to evacuate or protect assets when waters surge. The lack of enforced land-use planning means homes and critical infrastructure, such as the key market in the Ahwar Town and the Ruwais marina, continue to be built in highly exposed floodplains.[1]

Furthermore, widespread poverty severely limits financial capacity. Most households in communities like Al-Bahbah or Village of Al-Malha lack the savings to invest in flood-resilient construction to replace their vulnerable mud-brick homes. Public finances are also constrained, hindering large-scale investments in essential flood defenses such as retention dams in Wadi Ahwar, channel clearing, or the reinforcement of key bridges connecting dispersed villages.[2]

Adaptive Capacity to Drought & Water Scarcity:

Adaptive capacity for water scarcity presents a mixed picture. A key strength is the adoption of water-efficient technology. The use of drip irrigation on more than a quarter of farms, particularly in the more accessible areas of the Wadi Ahwar agricultural belt, is a significant positive factor that reduces sensitivity and serves as a foundation for broader intervention.[3]

However, this positive practice is overshadowed by major systemic constraints. Financial limitations hinder the large-scale investments required to move beyond incremental improvements. For instance, there is a critical need for large-scale water harvesting structures (e.g., dams in Wadi Dayqah or similar catchments) to capture torrential floodwater for use during dry periods, but these projects remain unrealized.[4] While

development plans may exist on paper, the lack of funding and institutional capacity prevents their implementation, leaving communities in elevated villages like Hanath persistently vulnerable to water shortages during droughts.[5]

6. Impacts Assessment framework

Assessment of climate change impacts for Ahwar district. The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 20: Assessment of climate change impacts for Ahwar district

	Criterion	Definition	Objective	Weight
1.	**Frequency of Occurrence**	Floods are a recurrent hazard (1996, 2021, 2023). Drought is a chronic stressor, exacerbated when floodwaters flow to the sea unused.	Prioritize interventions against the most recurrent shocks	12%
2.	**Severity of Impact**	Flood impact is catastrophic: loss of life, destruction of mud-brick homes (e.g., Al-Bahbah), erosion of Wadi Ahwar's soil, and damage to the Ruwais marina and Ahwar Market.	The flood has a high impact. The drought has impacts on the remote pastural villages	28%
3.	**Population Exposed to the Hazard**	Many people live in flood-prone Wadi Ahwar basin. Remote villages (e.g., Hanath, Al-Malha) are exposed to drought due to poor water access.	Target interventions to protect the largest number of people on and around the delta. But farmers also exposed to drought especially in remote areas	15%
4.	**Geographical Scope**	Floods impact the central Wadi Ahwar basin. Drought impacts remote, elevated villages.	Target areas mostly the delta with highest population density and economic value.	5%
5.	**Impact on Water and Agricultural Resources**	The economy is entirely dependent on climate-sensitive sectors, one delta and agriculture. Floods erode land in Wadi Ahwar; drought threatens water for dates, sesame, and livestock.	Protect the delta as one ecosystem	25%

6.	**Current Adaptive Capacity**	Capacity is very low due to poverty, lack of early warning systems, and incomplete projects (e.g., water harvesting), with limited plans for future interventions.	Prioritize addressing hazards the community cannot cope with, and support them with knowledge and capacity	10%
7.	**Presence of Vulnerable Groups in the Area**	While the presence of IDPs may be lower than in other districts, vulnerability is high among smallholder farmers, fishing communities reliant on the Ruwais marina, and residents of remote villages (Al-Malha, Hanath) who are geographically marginalized and have poor access to water and services.	Direct efforts towards protecting the most vulnerable livelihoods and addressing the specific challenges of geographically isolated communities	5%

2..3 Climate change vulnerability Aden governorate

2..3.1 Overview

Aden Governorate, a densely populated urban coastal center in Yemen, faces an acute and multidimensional climate crisis that exacerbates its existing humanitarian and infrastructural collapse. Its vulnerability is defined by extreme water scarcity, extreme heat, and exposure to sea-level rise, all set against a backdrop of prolonged conflict and institutional fragility. Aden faces multiple climate changes stresses from water scarcity, heat waves, floods, water salinity and sea level rise. Climate change in Aden is not a future threat but a current, relentless emergency. It acts as a threat multiplier, deepening water scarcity, damaging infrastructure, worsening public health, and fueling social tension in a city already on the brink. Effective response is hindered by the ongoing conflict, which limits adaptive capacity and redirects resources from long-term resilience to short-term humanitarian survival. All these impacts accelerated by conflict, political instability and economic challenges.

2..3.2 Climate Change Profile

Climate change scenarios (past and future), for main climate change indicators for Aden governorate, based in available data

Table 21: Climate change scenarios (past and future), for main climate change indicators for Aden governorate

Climate Indicator	Past Observation	Future Projection

Avg. Temp	The city of Aden is a benchmark for coastal warming, with studies showing a rate of **~+0.75°C/decade**	Projected increase aligned with the **Arabian Sea coastline** trend of **+3.5°C to +4.0°C**. Urban heat island effect will exacerbate this
Tmax	Coastal zone experiences high Tmax. The mean Tmax in Aden ranges between **25 and 32°C** annually	Projected severe increase of **+3.5°C to +4.0°C** for Tmax. This will drastically increase the duration and intensity of heatwaves.
Precipitation	Lies in a **very low-rainfall zone (<150mm/yr)**. Part of the arid coastal belt that showed **no statistically significant historical trend** in total annual rainfall	**High uncertainty. Likely to see no major change or a slight decrease in total volume, but a potential increase in the intensity of rare rainfall events**
Very Warm Days (≥35°C	**High baseline. The southern coastline of the Arabian Sea experiences around 100 days/yr of extreme heat**	Projected to see a **large increase of +80 to +100 additional days/year**, making extreme heat the norm for most of the year.
Sea Level Rise	*Historical rate of **3.3 mm/year** measured in Aden*	Projected to **accelerate to 5.9 mm/year or more** under high-emission scenarios (Al-Saafani et al., 2015)
Key Risks	*Heat waves, Saltwater intrusion, Coastal erosion, sea-level rise*	Extreme heat, flooding and sea level rise

Dominant Agro-Ecological Zone: Arabian Sea Coastline

Major Hazards

Table 22:Major hazards for Aden governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Water Scarcity	1	The paramount climate threat. Aden is in a permanent state of water stress. Groundwater is the sole source, and it is being extracted at a rate far exceeding recharge. Conflict has damaged infrastructure, leading to losses of over 40%. This chronic crisis is exacerbated by

		population growth, influx of IDPs, and increasing temperatures. It is a direct driver of disease, conflict, and economic hardship.
Heat Waves	2	Increasing in frequency, intensity, and duration. Extreme heat poses severe direct health risks (heatstroke, dehydration) and strains the energy grid needed for cooling. It accelerates evaporation from the scarce water reservoirs and increases domestic water demand, intensifying the water scarcity crisis. Vulnerable groups (elderly, children, outdoor workers) are at high risk.
Floods	3	Low frequency but high impact. Aden's rugged topography and largely impermeable surface, combined with clogged drainage systems, create perfect conditions for destructive flash floods during intense rainfall events. These events, while rare, cause immediate loss of life, damage to informal settlements and infrastructure, and disrupt the city's economy.
Water Salinity	4	A creeping, irreversible crisis. Saltwater intrusion into coastal aquifers is advanced due to sea-level rise and massive over-extraction of groundwater, which lowers the water table and pulls seawater inland. This renders wells unusable for drinking and irrigation, permanently reducing the already scarce freshwater resources.
Sea Level Rise & Coastal Erosion	5	A long-term existential threat. As a peninsula, Aden is highly exposed. SLR threatens critical infrastructure: the Aden Port, oil refineries, the airport, and coastal roads. It exacerbates flooding and saltwater intrusion. Coastal erosion is already damaging properties and ecosystems.
Drought	6	Rainfall is already low and climate projections suggest a potential decrease in total rainfall. Aden depends on a water field on Lahej governorate. Drought impacted agriculture areas around Aden towards Lahej but also make stress on water greenery in the city.
Rain Variability	7	Rainfall is already low and erratic. Climate projections suggest a potential decrease in total rainfall but an increase in the intensity of individual rainfall events. This pattern worsens both drought and flood risks—long dry spells are punctuated by short, destructive downpours that the landscape cannot absorb.

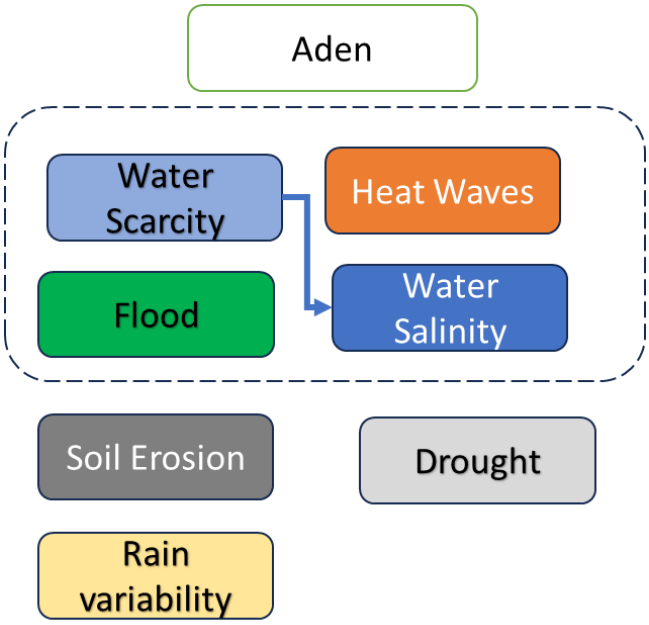
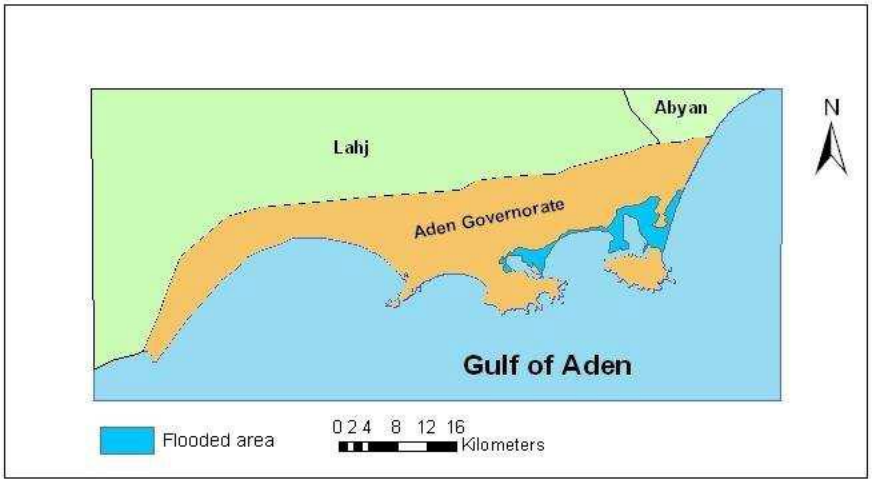


Figure 12: Aden governorate climate change hazards/risks interlink, water scarcity and salinity are the main climate change impacts

Exposure

Aden Governorate, with its coastal urban setting and minimal agricultural land, is highly exposed to climate hazards—particularly sea-level rise, storm surges, flooding, and heatwaves. Though agriculture plays a limited role in Aden's economy, the region's dense population of over 1.4 million people[75], including tens of thousands of internally displaced persons (IDPs) from other conflict-affected areas, increases its exposure to risk. Low-lying areas such as Crater, Al-Tawahi, Khor Maksar, and Al-Mualla are especially vulnerable due to their proximity to the shoreline and aging urban infrastructure. Climate modeling projects sea levels in the area could rise by 33–60 mm annually, threatening 5–6% of coastal zones with inundation and damaging homes, roads, and public facilities (ResearchGate, 2016). Exposure is also magnified by the scarcity of renewable water resources: the Tuban Delta, which historically served as the governorate's primary water source, now delivers only 53 million m³ against a demand of 136.4 million m³ as of 2022 (World Green Economy Org, 2024). Critical infrastructure such as hospitals, ports, schools, and power stations are clustered near the coastline—further increasing the area's exposure. Moreover, Aden lacks expansive critical ecosystems such as wetlands or forests that might provide natural buffers against climate events, making it dependent on engineered solutions which are currently lacking or degraded.

[75] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen



Map 8: Aden Governorate showing the expected inundated area due to the SLR of 33 and 60 cm.[76]

Sensitivity

Aden's sensitivity to climate hazards is shaped by the vulnerability of its population, the fragility of its infrastructure, and the imbalance between water demand and supply. Although agriculture is limited, small plots—mainly in Dar Saad and Sheikh Othman—still depend on traditional irrigation and are highly sensitive to rainfall variability and salinization. The city's critical infrastructure, such as the Aden oil refinery, transport corridors, and health centers, is particularly sensitive to flooding and heat damage due to poor maintenance and limited climate-proofing. Social sensitivity is further exacerbated by the composition of the population: IDPs, women, children, and people living in informal settlements lack access to stable housing, clean water, and health services. In 2022, more than 61% of Yemen's population, including residents of Aden, lacked access to safe drinking water, increasing exposure to waterborne diseases like cholera and dengue, especially after heavy rainfall (DevDiscourse, 2024). The water balance continues to worsen; projections estimate the water deficit could reach 147 million m³ by 2050, putting stress on already fragile supply networks. Moreover, traditional systems like the Tawila Cisterns, which historically played a role in flood mitigation, are now largely non-functional—with only 13 out of 53 tanks surviving. These deteriorating assets reflect the city's increasing sensitivity to climate-induced hazards.

Adaptive capacity

Aden's adaptive capacity is currently constrained by its limited institutional readiness, inadequate technical skills, and scarce financial resources. While some traditional systems, like the Tawila Cisterns, offer local knowledge for water management, their decline symbolizes the erosion of community-based adaptation. In terms of institutional preparedness, the governorate lacks a formalized climate adaptation or disaster risk management plan that addresses its specific vulnerabilities. There is minimal investment in climate-resilient

[76] Al Saafani, M. A., et al. "Impact of sea level rise and climate change on the coastal zone of Aden governorate, Republic of Yemen." *Faculty of Science Bulletin* 27 (2015): 15-32

infrastructure, such as desalination plants or modern drainage systems, although a proposal for a 160,000 m³/day desalination facility has been put forward (World Green Economy Org, 2024). In the agricultural sector—though limited in scale—efficient irrigation technologies and drought-resistant crop practices are virtually absent, reflecting a lack of technical extension services and climate-smart planning. Moreover, many frontline institutions in Aden lack trained personnel, climate data, and access to climate financing. Human capacity is also challenged by the ongoing conflict, with many qualified professionals having left the area. While local communities show strong social cohesion and informal coping mechanisms, these are increasingly stretched and insufficient to meet the scale of current and future climate shocks. Enhancing Aden's adaptive capacity will require integrated planning, investment in infrastructure, and capacity building tailored to its unique urban-coastal context.

Impacts Assessment framework

Assessment of climate change impacts for Aden governorate. The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 23: Assessment of climate change impacts for Aden governorate

	Criterion	Definition	Objective	Weight (%)
1.	**Frequency of Occurrence**	Water scarcity is a constant, daily reality. The Aden water supply system has been in crisis for decades, with shortages worsening dramatically since the 2015 escalation of conflict. Heat is chronic for 8-9 months of the year, with acute waves occurring multiple times annually. Flash floods are less frequent but recurrent; significant events were recorded in 2019, 2020, 2021, and 2023, each causing casualties and displacement..	Water scarcity is daily reality so desalination and other water management techniques is priority	20
2.	**Severity of Impact**	In Aden, the water scarcity leads to conflict; in June 2023, clashes were reported in Sheikh Othman district over water access. Floods: The April 2020 flood in Khor Maksar and other districts killed at least 10 people, displaced thousands, and damaged the Aden International Airport and roads, isolating communities. Heat: A 2021 study linked extreme heat to increased morbidity and mortality, especially among IDPs and outdoor laborers.	The damages resulting from flood is high so intervention for flood management and resilient infrastructure is needed	25

3.	**Population Exposed to the Hazard**	Nearly 100% of Aden's estimated 1.5+ million residents (including over 140,000 IDPs) are exposed to water scarcity and extreme heat. Flooding: A significant portion of the population living in topographical low points like Khor Maksar basin, Dar Sad, and informal settlements across the city are exposed. For example, the Al-Gambi area (informal settlement) is highly flood-prone.	Target interventions to protect all people in Aden	15
4.	**Geographical Scope**	Water scarcity and heat are governorate-wide. Flooding is concentrated in specific topographical basins: primarily on wadi outlet in Al-boriqa and Bir Ahmed, Khor Maksar, also parts of Sheikh Othman, Al-Mansura, and Dar Sad. Salinity is focused on the coastal aquifer zone, severely impacting wells in Al-Mualla, Craiter, and Attawahi.	Wadi tuban outlet for flood protection and water scarcity everywhere	10
5.	**Impact on Water and Agricultural Resources**	Water scarcity directly impacts the single most critical resource. The Bir Ahmed aquifers are critically over-exploited.	Wise use of available water and search for alternatives such as desalination	20
6.	**Current Adaptive Capacity**	Capacity is extremely low. The local water corporation lacks resources; a 2023 INGO report noted that >40% of water is lost through leaks in the damaged network. There is no functional city-wide early warning system for floods. Institutional and financial challenges.	Improving, and re-activating the water pricing for the city. Maintenance and installing early warning system	5
7.	**Presence of Vulnerable Groups in the Area**	The presence of over 140,000 IDPs (OCHA, 2023), many living in informal settlements like those in Khor Maksar or on the outskirts of Sheikh Othman, drastically increases vulnerability. These groups often reside in the most hazardous locations (plains, areas with no piped water), live in fragile shelters, and have no financial safety net, making them disproportionately affected by any climate shock.	Direct efforts towards protecting the most vulnerable groups	5

2..4 Climate change vulnerability Hodeidah governorate

2..4.1 Overview

The southern districts of Al Hudaydah—Al Khukha, Hays, and Al Tuhayta—form a vast, vulnerable, and strategically significant region along Yemen's Red Sea coast. Home to an estimated 500,000 to 600,000 people, with over 184 thousands in Al-khokhah and Hays districts[77], this area has become a fragile haven for those displaced by conflict, with Al Khukha district alone hosting approximately 35,000 Internally Displaced Persons (IDPs) as of 2023. These three districts sprawl across the Tihama plain, with Al Tuhayta being the largest at roughly 1,500 km², a geography that defines both their livelihoods and their vulnerabilities.

Life here is characterized by profound hardship. The socio-economic fabric has been torn by years of conflict and increasingly frequent climate shocks. Over 80% of the population lives below the poverty line, and a severe food security crisis means a high percentage of families survive only on humanitarian assistance, classified in Crisis or Emergency levels of hunger. The local economy is sustained by four critical pillars: agriculture, which cultivates an estimated 60,000 hectares of sorghum, millet, and sesame; small-scale fishing along the coast, particularly near Al Khukha and Al Tuhayta; pastoralism, where livestock represents a key store of wealth; and precarious trade and labor opportunities around the volatile Al Khukha border crossing and the vital coastal highway.

The environment these communities must survive in is inherently harsh and becoming more extreme. The climate is a quintessential hot desert, with average annual temperatures hovering around 30°C (86°F). The summer months are brutal, consistently exceeding 40°C (104°F) and often reaching life-threatening heatwaves above 45°C (113°F), exacerbated by high year-round humidity. Rain is both scarce and destructive. With an annual average of less than 100 mm, precipitation arrives not as a gentle replenishment but in short, violent bursts during the March-May and July-September seasons. This erratic pattern fails to recharge aquifers effectively and instead triggers devastating flash floods.

This climatic reality is amplified by the region's topography. The entire area is part of the flat, low-lying Tihama plain, with most land sitting between 0 and 50 meters above sea level. This makes it acutely susceptible to sea-level rise and saltwater contamination of its groundwater. The plain is scarred by major wadis—seasonal river valleys like Wadi Rima and Wadi Mawr—which are dry for most of the year but transform into powerful torrents during rains, spreading floodwaters across the land and shaping the lives and risks of those who live there.

2..4.2 Climate Changes Profile

Climate change scenarios (past and future), for main climate change indicators for Hodiedah governorate, based on available scenarios

[77] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

Table 24: Climate change scenarios (past and future), for main climate change indicators for Hodiedah governorate

Climate Indicator	Past Observation	Future Projection
Avg. Temp	Significant warming observed. The city of **Hodeidah itself showed a rate of change exceeding +0.75°C/decade** between 1985-2019 (Iraqi & AbdAlla, 2021).	Projected increase aligned with the **Red Sea coastline** trend of **+3.5°C to +4.0°C**. This is among the highest projected increases globally.
Tmax	The **Red Sea coastline** shows some of the **highest mean Tmax values (30-35°C)** in the country and a significant increasing trend)	Projected to be in the zone of **highest increase (+3.5°C to +4.0°C)**. The number of days with extreme heat will surge
Precipitation	Part of the **Red Sea and Tihama agroecological zone**, characterized by low rainfall. The governorate showed **no statistically significant historical trend** in total annual rainfall.	**High uncertainty.** Likely to see a **slight decrease or no major change** in total volume, but with a **significant increase in the intensity of individual rainfall events**
Very Warm Days (≥35°C	**Extremely high baseline (150-180 days/yr)** – the highest in Yemen (Fig 9a, FAO). Experienced a **statistically significant increase** of up to +1.4 days/year	Projected to see one of the **most severe increases nationally**: **+100 or more additional days per year**.
Sea Level Rise	*Governorate has a long, low-lying coastline. Historical rate of* ***~3.3 mm/year*** *observed*	Projected to **accelerate to 5.9 mm/year or more** under high-emission scenarios
Key Risks	*Coastal erosion, sea-level rise, extreme heat stress on agriculture and population*	Extreme heat, flooding and sea level rise

Dominant Agro-Ecological Zone: Red Sea and Tihama plain

2..4.3 Major Hazards

Table 25: Major hazards for Hodiedah governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Flash Floods	1	The western slopes funnel intense rainfall through vast wadi systems (e.g., Wadi Rima, Wadi Siham, Wadi Mawr) into the coastal plains. In April 2020, floods affected 14,000+ people in Hays and Al Tuhayta, destroying homes and farmland. In July 2021 and August 2022, similar events recurred, damaging the coastal highway near Al Khukha and isolating communities.
Heat Waves	2	Temperatures regularly exceed 40°C (104°F) from May-September. In June 2023, a severe heatwave with temperatures over 45°C (113°F) was recorded, causing heat stress incidents and increasing water demand for both people and livestock.
Water Salinity	3	Coastal aquifers are the primary source. In Al Tuhayta district, salinity levels in wells exceed 3,000 µS/cm (WHO limit for drinking is 1,000 µS/cm), forcing reliance on trucked water at ~5,000 YER/m³. Over-extraction near Al Khukha has caused wells to be abandoned due to saltwater intrusion.
Sea-level rise and coastal erosion	4	The low-lying coastline (parts < 2m elevation) of Al Tuhayta is highly vulnerable. A 2021 UNEP assessment noted coastal erosion rates of 1-2 meters per year in some areas, threatening coastal roads and communities like Al-Qanawis. Mangrove ecosystems near Al Khukha are degraded.
Drought	5	From 2018-2021, the region experienced a prolonged dry spell, reducing groundwater recharge. In Hays district, communities reported wells drying up to depths of 80-100 meters, leading to crop failure and exacerbating cholera outbreaks due to lack of clean water.
Water Scarcity	6	This is a critical risk driven by the hazards above. In Al Khukha, only 40% of the population has reliable access to safe water due to salinity and drought. The average water availability is estimated at < 50 liters/person/day, far below the SPHERE standard of 15 l/p/d.

Rain Variability	7	The key concern is unpredictability. In 2022, Hays received its annual rainfall in just 3 intense events over two weeks, causing floods but failing to recharge aquifers effectively, followed by a prolonged dry period that stressed crops.

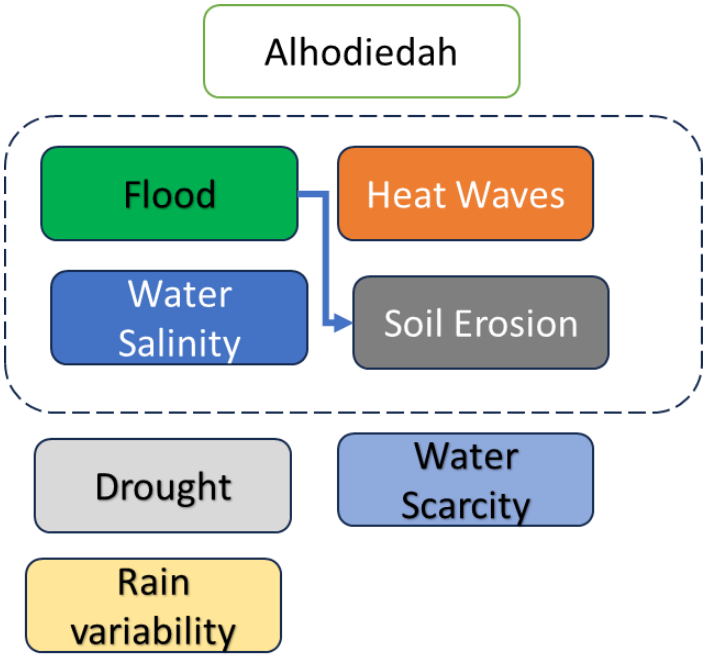


Figure 13: Hodiedah governorate climate change hazards/risks interlink, flood and increase temparature are the main climate change drivers. (focused on Al-khukhah, Hays and Al-tuhaitah districts)

2..4.4 Exposure

The exposure is extreme. The entire area is a vast, flat alluvial plain. Critical infrastructure—including the vital Mocha-Hodeidah coastal highway, Hays Central Prison, and Al Khukha Hospital—are built directly within the flood plains of Wadi Rima and Wadi Siham. Entire communities, such as those in the low-lying areas of Al Tuhayta district and the villages along the wadi paths like Zabid and Bait Al-Faqih, are in the direct path of floods. The coastline, particularly around Al-Mandhar and Al-Qanawis in Al Tuhayta, is low-lying, exposing aquifers to saline intrusion.

2..4.5 Sensitivity

The high dependency on exposed agriculture makes the system profoundly sensitive. The fertile lands of Wadi Rima's floodplain (est. ~10,000 Ha in Hays alone) are the sole source of livelihood. A 2021 flood deposited over ** half a meter of silt** on farms in Hays, destroying that season's sorghum and millet harvest. The presence of ~45,000 IDPs (IOM DTM, 2023), often living in flimsy shelters on the outskirts

of Al Khukha town or on rented farmland in Hays, drastically increases sensitivity; they have nowhere to go and no resources to recover.

Al Hudaydah governorate in Yemen is highly sensitive to heat waves due to its hot climate, coastal location, and widespread socio-economic vulnerabilities. Summer temperatures frequently exceed 35–38 °C, with high humidity intensifying heat stress, especially in low-lying coastal areas. The region's fragile infrastructure—including frequent power outages and limited access to clean water and healthcare—makes it difficult for residents to cope with extreme heat.

While drought-resistant crops provide a buffer, the reliance remains a critical vulnerability. When floods destroy crops or salinity ruins wells in Al Tuhayta, the entire local economy seizes. The over-exploitation of the aquifer is severe. In Al Khukha, the water table has dropped over 15 meters in the last decade, and salinity has increased by 30% in many wells (FAO, 2021), immediately threatening the last remaining productive farms and making the entire system highly sensitive to any climatic shift.

2..4.6 **Adaptive capacity**

The adaptive capacity is severely constrained. Poverty is widespread, with over 80% of the population in these districts living below the poverty line (World Bank, 2020), preventing investment in deeper wells or resilient homes. Local governance is weak due to the conflict, resulting in no enforced water extraction regulations or coordinated disaster plans.

The adaptive capacity to heat waves in Al Hudaydah is low due to limited infrastructure, weak healthcare systems, and widespread poverty. Most communities lack reliable electricity for cooling, clean water for hydration, and adequate shelter to protect against extreme heat

Existing knowledge is based on past experience, which is becoming less reliable. There are no functional early warning systems for floods; during the July 2021 floods, communities in Wadi Rima had only minutes of warning. Water management is individualistic, leading to a "tragedy of the commons" where the competitive drilling of deeper wells in Al Khukha accelerates salinization for everyone.

External support from INGOs like CARE and DRC is critical but project-based. For example, a 2022 project in Hays provided emergency water trucking but could not fund the rehabilitation of the main saline-contaminated aquifer. The lack of financial services means a single flood can push a family into irreversible debt, as seen when farmers in Al Tuhayta lost their entire sesame crop worth ~$2,000 per hectare in the 2020 floods.

2..4.7 **Impacts Assessment framework**

Assessment of climate change impacts for Hodiedah governorate (focusing on three target districts). The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 26: Assessment of climate change impacts for Hodiedah governorate

	Criterion	Definition	Objective	Weight (%)
1.	**Frequency of Occurrence**	Floods are now a near-annual event. Major events were recorded in April 2020, July 2021, August 2022, and April 2023, each affecting tens of thousands across Wadi Rima's floodplain. Salinization is a continuous process, with reports from Al Tuhayta showing a 30% increase in well salinity over the past decade.	Flood become frequent event and need to be addressed	20
2.	**Severity of Impact**	Flood impact is catastrophic. The July 2021 flood in Hays destroyed over 400 homes and inundated ~2,000 hectares of farmland with silt. Salinization in coastal Al Khukha has permanently degraded an estimated 1,500 hectares of agricultural land, rendering it uncultivable.	The flood has a high impact. The salinity has impacts on coastal areas	25
3.	**Population Exposed to the Hazard**	A very high percentage of the population is exposed. An estimated 300,000+ people live in the flood-prone basins of Wadi Rima and Wadi Mawr. Nearly all 500,000+ residents of the three districts are exposed to water salinity and scarcity, as groundwater is the sole source for most. Heat waves is an impact that many people exposed to especially farmers and students	Target interventions to protect the people on the flooded areas, especially that Al-hodiedah is a plain for many wadies that flow from highlands. Heat waves need to be addressed for weak groups such as farmers and students	
4.	**Geographical Scope**	Floods impact all major wadi systems, but most severely affect central Hays district. Salinization affects the entire 220 km coastline of the three districts, with the most acute impacts within 5 km of the shore in Al Tuhayta. Drought can be widespread, but impacts remote, elevated villages like	Mostly all areas impacted by flood, heat waves, salinity and water scarcity	10

		those in eastern Al Khukha most severely.		
5.	**Impact on Water and Agricultural Resources**	The local economy is entirely dependent on climate-sensitive sectors. The April 2020 flood destroyed 70% of the sesame crop in parts of Hays, a key cash crop. Salinization forces 90% of households in Al-Mandhar (Al Tuhayta) to rely on expensive trucked water, costing families ~30% of their monthly income.	Agriculture directly impacted by flood	15
6.	**Current Adaptive Capacity**	capacity is extremely low. No functional early warning systems exist for floods. After the 2022 floods, only 20% of affected families in Al Khukha received any external assistance. Water management is individualistic; in Hays, the competitive drilling of deeper wells accelerates community-wide salinization.	Prioritize addressing early warning system and wells management	
7.	**Presence of Vulnerable Groups in the Area**	High presence of ~45,000 IDPs in Al Khukha and Hays, often living in the most hazardous locations like wadi beds. Female-headed households and poor smallholder farmers in villages like Zabid (Hays) are geographically marginalized and have poor access to alternative water sources when theirs fail.	Direct efforts towards protecting the most vulnerable groups such as IDPs, Female-headed households and poor smallholder farmers	

2..5 1.5 Climate change vulnerability Hadramout governorate

2..5.1 Overview

Coastal Hadramout is approximately 300 km (BIKs, 2010), arid region defined by its complex relationship with the sea and the desert. Its landscape is a dramatic mix of rugged, mountainous plateaus that descend sharply to a narrow coastal plain, rarely exceeding 10 km in width in many areas, fringed by long stretches of sandy shoreline. The climate is harshly tropical, characterized by intense year-round heat, with average summer temperatures often exceeding 35°C and reaching highs above 40°C, stifling humidity, and minimal, erratic rainfall averaging less than 50 mm per year (TNC-BUR, 2016), making it one of the hottest places on earth.

The lifeblood of this region is the city of Al Mukalla, the governorate's bustling capital and economic heart. With an estimated population of over 300,000 people[78], it is a dense urban center where much of the region's activity is concentrated. The city's economy is driven by its strategic port—a critical national gateway for over 70% of Yemen's commercial imports and humanitarian aid (World Bank, 2023)—fishing, commerce, and a growing service sector. Beyond the city, smaller towns like the historic port of Al-Shihr (population ~50,000) and the fishing village of Fuwah dot the coast, their livelihoods inextricably tied to the ocean.

For centuries, the primary livelihood has been fishing. The artisanal fleet, comprising an estimated 5,000+ boats, harvests the rich marine resources of the Arabian Sea, providing income and food security for tens of thousands of households (FAO, 2021). Inland, the wadis that cut through the coastal mountains, such as Wadi Gheil and Wadi Bin Ghanim, support pockets of agriculture on roughly 5,000-7,000 hectares of cultivated land (local agricultural ministry estimates). Here, farmers rely on sparse surface water and groundwater to grow date palms, sorghum, and vegetables, practicing a resilient but vulnerable form of desert agriculture.

Yet, this existence is precarious. The region faces a profound water crisis. The primary source, the Al-Mukalla aquifer, is severely over-exploited, with extraction rates far exceeding natural recharge, leading to plummeting water tables (TNC-BUR, 2016). Compounding this is the silent creep of seawater intrusion, where saltwater has contaminated wells up to 2 km inland in some areas, a problem exacerbated by over-pumping and sea-level rise estimated at ~3-5 mm per year (TNC-BUR, 2016).

Coastal Hadramout is thus a place of contrasts: a urban center thriving on trade against a backdrop of environmental scarcity, where traditional livelihoods forged in austerity are being tested by modern pressures and a changing climate. Its future depends on balancing the demands of its growing population with the fragile, finite resources of its arid shore.

2..5.2 Climate Changes Profile

Climate change scenarios (past and future), for main climate change indicators for Hadramout governorate, based on available documents

Table 27: Climate change scenarios (past and future), for main climate change indicators for Hadramout governorate

Climate Indicator	Past Observation	Future Projection
Avg. Temp	Southern coastal areas saw the **slowest warming** in Yemen (**+0.18 to +0.36°C** total	Projections show strong internal variation. The **northern parts of Hadramout** are in a zone of **+4.0°C to +4.5°C** increase. The **coastal**

[78] Population estimation 2025 Displacement Tracking Matrix – IOM, Yemen

	1981-2016). Interior areas warmed faster.	**areas** align with the Arabian Sea projection of **+3.5°C to +4.0°C**.
Tmax	Eastern parts (incl. Hadramout) showed a high rate of increase, estimated at **+0.04°C/yr or more** (~+1.4°C+ total 1981-2016).	Northern interior areas project some of the **highest increases in the country (+4.0°C to +4.5°C)**. Coastal increases are severe but slightly lower
Precipitation	coastal areas receive **<150mm/yr**, while interior areas are hyper-arid. Eastern parts experienced a precipitation decline (**-18 to -36mm** total 1981-2016), though not statistically significant	**Expected to remain very dry. Increase of cyclones. A key projected change is higher inter-annual variability.**
Very Warm Days (≥35°C	**Northern parts of Hadramout had a high baseline (100+ days/yr). The interior parts bordering Oman saw an additional very warm day per year since 1981**	Projected to see a **large increase**, though slightly less extreme than the western coastline. Expect **+60 to +80 additional days/year** in the interior..
Sea Level Rise	*Governorate has a long, low-lying coastline. Historical rate of **~3.3 mm/year** observed*	Projected to **accelerate to 5.9 mm/year or more**. This threatens the entire coastal strip, including the key port of **Mukalla**
Key Risks	*Cyclones, coastal erosion, sea-level rise, extreme heat stress on agriculture and population*	Increased intensity of cyclones and associated flooding, extreme heat in the interior rendering areas uninhabitable, severe water scarcity

Dominant Agro-Ecological Zone: Arabian Sea Coastline (south), Desert (north), Internal Plateau (center)

2..5.3 Major Hazards

Table 28: Major hazards for Hadramout governorates can be summarized as follow:

Hazard	Ranking	Explanation & Context
Heat Waves	1	Increasing frequency and intensity of heat waves, especially in the urban environment of Al Mukalla which experiences the urban heat island effect. This stresses water resources, increases energy demand for cooling, and poses health risks to the population, especially workers on open spaces and students.
Water Scarcity	2	Although Al-Mukalla aquifer is one of the largest groundwater basin in Yemen, but severely over-exploited to meet the city's demand (TNC-BUR, 6). Urabn Al-mukalla district face real water scarcity with limited water in the wells.
Flash Flood	3	The catchment areas surrounding Al Mukalla (e.g., Wadi Al-Shu'oot) are highly prone to flash floods. Major events in 2020 and 2023 caused catastrophic damage in the city, submerging neighborhoods (e.g., Al-Shihr District), destroying the Al-Shihr Road (a vital economic link), and damaging homes and infrastructure. Floods also rip through rural wadis, destroying farms and isolating communities.
Sea Level Rise and Coastal Erosion	4	The TNC-BUR (2016) report specifically identifies this as a critical threat. A 0.5 to 1-meter rise would inundate low-lying parts of Al Mukalla's corniche, the vital Al Mukalla Port (a lifeline for humanitarian and commercial goods), the airport, and desalination plants. Coastal erosion already threatens infrastructure and historical sites.
Water Salinity	5	Directly linked to over-pumping- especially from Ghail Ba-wazir and sea-level rise. The TNC-BUR (2016) assessment confirms saltwater intrusion into the Al-Mukalla aquifer, degrading the primary source of drinking water for the city. This renders groundwater unsuitable for drinking and irrigation in coastal areas of the district.
Rain Variability	6	Irregular timing and intensity of rains disrupt any remaining rain-fed agriculture in the rural districts and paradoxically intensify flood risk in Al Mukalla, as short, intense downpours overwhelm the inadequate drainage system.
Drought	7	Perceived as a lower immediate priority and linked to water scarcity

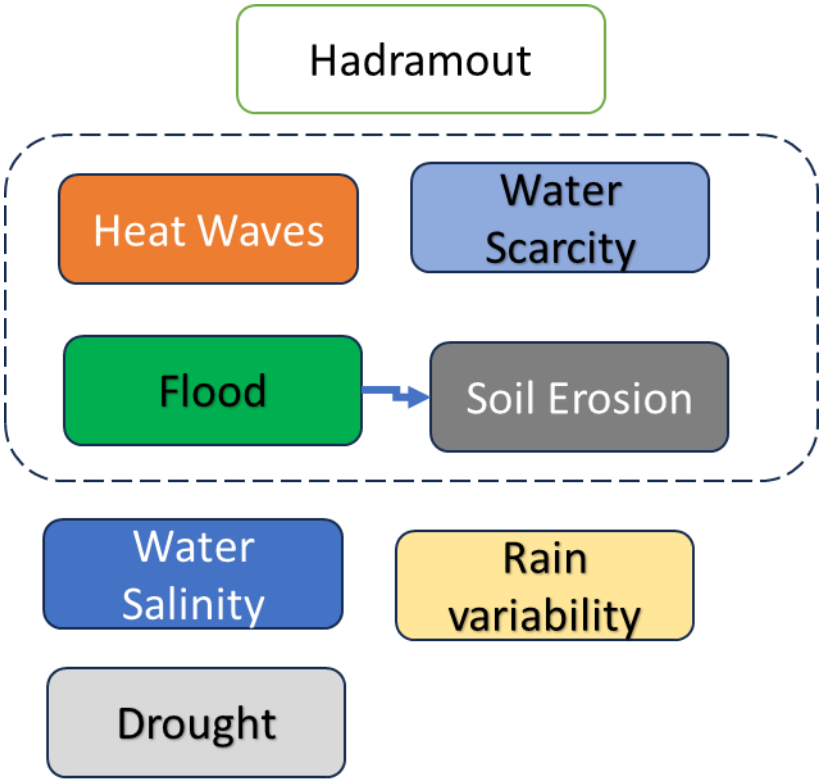


Figure 14: Hadramout climate change hazards/risks interlink, heat waves is one of the major hazards especially in the city of Al-Mukalla, water scarcity and flood is a main climate change drivers (focused on Al-Mukalla and Rural Al-Mukalla districts).

Al Mukalla and rural Al-Mukalla districts, water scarcity is the paramount issue, driven by drought and demand. Flooding is a frequent and destructive acute hazard. Critically sea level rise and coastal erosion as a severe long-term threat specifically for Al Mukalla's infrastructure.

2..5.4 **Exposure**

Al Mukalla's urban core is increasingly exposed to the harsh realities of heat waves. Expanding the city on the coastal area, make high exposed to heat waves especially outside worker or students in unprepared study environment. The city's vital infrastructure—its port, airport, power stations, and densely populated neighborhoods—is perched on a low-lying coastal strip. Satellite data reveals that sea levels along Yemen's coast have been rising at an average of **3 mm per year since 1993**, and cumulative projections estimate a total rise of **0.54 m by 2100**. Such a rise threatens to flood critical assets, disrupt humanitarian aid routes, and undermine commerce throughout the region Sana'a Center For Strategic Studies.

Meanwhile, the city endures sharp, unpredictable threats from inland. In 2020, Yemen suffered extensive flash floods: nearly 300,000 people lost their homes, crops, livestock, and belongings, and almost 96,000 families were affected across 19 governorates. In Hadramaut province and areas surrounding Al Mukalla, such flooding displaced hundreds of families, destroyed infrastructure, and left roads impassable—highlighting the acute risk posed by sudden downpours.

Beyond the city, rural and peri-urban communities face a mounting water crisis driven by severe groundwater depletion and salinization. Though precise figures for Al Mukalla are sparse, Yemen's nationwide situation offers compelling context. In critical basins like Tuban-Abyan, groundwater levels are falling by about 1 m per year, and in Sana'a Basin, they're plummeting by 6–8 m annually. This trend reflects broader patterns of overextraction that similarly affect the region's shared Al-Mukalla aquifer.

Geological studies show that the Mukalla Sandstone aquifer is vast and productive—up to 300–400 m thick with high transmissivity of 3,000–3,500 m²/day Scribd. However, these reserves are under intense stress: Yemen pumps approximately 1,500 million cubic meters annually from its aquifers—exceeding recharge rates—but only about 800 MCM/year is licensed Scribd.

Groundwater depletion has dire consequences. Over-pumping creates a vacuum that allows **seawater intrusion**, contaminating wells and raising salinity levels—a threat documented in coastal areas across the Arabian Peninsula ResearchGate+1Sana'a Center For Strategic Studies. In this way, urban water stress and rural agricultural decline are intertwined, creating a regional water crisis with cascading effects.

2..5.5 **Sensitivity**

The sensitivity of these two districts is very high, determined by the fragile nature of the exposed assets and the socio-economic vulnerability of the population. The presence of over 100,000 Internally Displaced Persons (IDPs) in Hadramout (IOM DTM, 2023), many concentrated in informal settlements in Al Mukalla City (e.g., in the Al-Shihr suburb and within the Wadi Al-Shu'oot basin), drastically increases sensitivity. These groups often live in flimsy shelters highly susceptible to floods and heatwaves, have limited assets, and lack safety nets. On the other side students-especially children- who study in unprepared study environment are high sensitive to heat waves but till now nobody in Yemen identify it as a climate change impact. Women, children, and the elderly in these communities are disproportionately affected by water scarcity and health impacts of heat. The Port of Al Mukalla and the Al Mukalla Airport are of paramount national importance but are highly sensitive to sea-level rise and coastal erosion. Inundation or damage would sever a lifeline for humanitarian aid and commerce for the entire country. Critical urban infrastructure, like the Al-Shihr Road, has proven highly sensitive to flash floods, as seen in its destruction in 2020. The entire region's sensitivity is defined by its total dependence on the Al-Mukalla aquifer. This system is highly sensitive to over-extraction and sea-level rise, with saltwater intrusion documented up to 2 km inland (TNC-BUR, 2016). The lack of alternative water sources means any decline in quality or quantity creates an immediate crisis. In Rural Al Mukalla, livelihoods are acutely sensitive to water scarcity. Agro-pastoral activities, which are the primary income source, rely on wadi flows and groundwater. The cultivation of drought-sensitive crops and the reliance on livestock that require steady water access make these livelihoods highly vulnerable to drought and well failure.

2..5.6 **Adaptive capacity**

The adaptive capacity across both districts is low to very low, crippled by a lack of resources, planning, and institutional fragility. The 2016 TNC-BUR report provided a detailed vulnerability assessment and adaptation plan for the coastal zone; its implementation has been severely limited. There is no comprehensive, operational early warning system for flash floods targeting informal settlements. Disaster management is largely reactive, focused on emergency response led by organizations like the Yemen Red

Crescent and ICRC, rather than proactive risk reduction. Many classrooms lack proper ventilation, fans, or air conditioning, making learning difficult and increasing the risk of heat-related illnesses during hot periods. Power outages and water shortages further reduce students' ability to stay hydrated and cool. While some schools may adjust schedules or close during extreme heat, these measures are inconsistent and not always effective.

Rural Al Mukalla, agricultural practices remain largely traditional and inefficient. The widespread use of flood irrigation, instead of modern drip or sprinkler systems, leads to significant water waste, further stressing the sensitive aquifer. Farmers have limited access to drought-resistant seeds or knowledge of climate-smart agriculture techniques. Adaptive capacity is severely hampered by a lack of financial resources. The local authority lacks the budget for large-scale adaptation projects, such as constructing coastal defenses, rehabilitating the water network to reduce leakage, or building dams in western wadis for floodwater harvesting. Households, especially IDPs and the rural poor, cannot afford the high cost of adaptive measures like water tanks, air conditioning, or reinforcing their homes. Technical capacity within local institutions is stretched thin. While Hadramout University provides valuable expertise, translating research into actionable policy on the ground is a major challenge. Knowledge of climate risks exists at a high level but has not been effectively disseminated to all communities, particularly in remote areas of Rural Al Mukalla, to drive behavioral change at the household level. In summary, the high sensitivity of people, infrastructure, and livelihoods is met with a low adaptive capacity, creating a critical vulnerability gap. The region is highly exposed to climate hazards and lacks the resources, plans, and financial means to effectively cope with or adapt to them.

2..5.7 Impacts Assessment framework

Assessment of climate change impacts for Hadramout (focusing on target districts). The weights reflect the district's specific context, prioritizing objectives on its agricultural economy and general adaptation options.

Table 29: Assessment of climate change impacts for Hadramout

	Criterion	Definition	Objective	Weight (%)
1.	**Frequency of Occurrence**	Heat waves, drought and water scarcity are chronic, ongoing hazards. Flash floods are recurrent, with major events occurring every few years (2008, 2015, 2020, 2023). This high frequency demands constant adaptation.	Prioritize to heat waves because it is long year event. The flood and cyclones impacts especially within the city	20
2.	**Severity of Impact**	Flood impact is catastrophic and immediate (e.g., 2020 floods destroying thousands of homes and farms). Drought impact is severe but slow-onset, leading to	The flood has a high impact. The drought has impacts on Rural Al-Mukalla	20

		livelihood collapse, displacement, and water conflicts. Both have high severity.		
3.	**Population Exposed to the Hazard**	Flash floods expose hundreds of thousands living in the city of Al-Mukalla and wadies in Rual Al-Mukalla districts, drought more on Rual Al-Mukalla	Focusing on Al-Mukalla district	15
4.	**Geographical Scope**	Drought exposes nearly the entire rural population. Flash floods expose hundreds of thousands living in the Al-Mukalla city	Target areas mostly Mukalla and surrounding wadies	15
5.	**Impact on Water and Agricultural Resources**	This is the core vulnerability. Drought directly causes agricultural failure and aquifer depletion. Floods destroy topsoil and damage infrastructure needed for agriculture (e.g., roads, markets). Protecting these resources is paramount.	Protect rural livelihoods	15
6.	**Current Adaptive Capacity**	Capacity is very low due to political instability, conflict, and weak institutions. The lack of effective water governance, modern irrigation, and water storage infrastructure means communities cannot cope with these shocks without external assistance.	Prioritize addressing overall management of hazards especially flood and cyclones, early warning system is neccessary	
7.	**Presence of Vulnerable Groups in the Area**	Vulnerability is high among smallholder farmers, IDPs (concentrated in Al Mukalla), pastoralists in Rural Al-Mukalla	Direct efforts towards protecting the most vulnerable livelihoods	

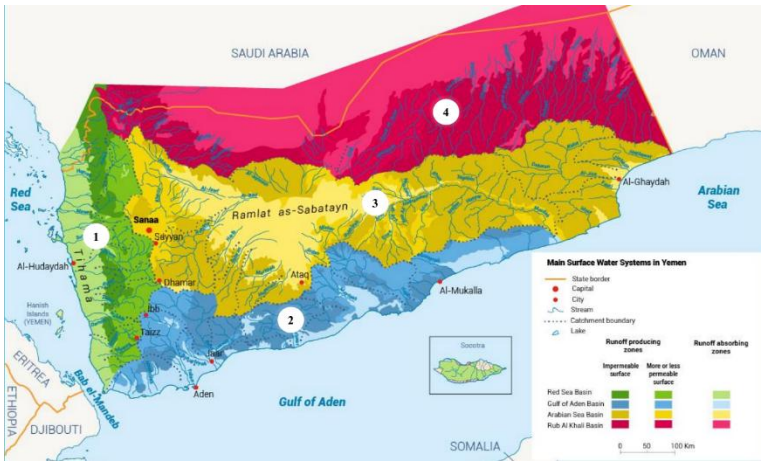
Water Management

CHAPTER 3

Water Management

6.1 Water resources Context in Project Targeted Governorates

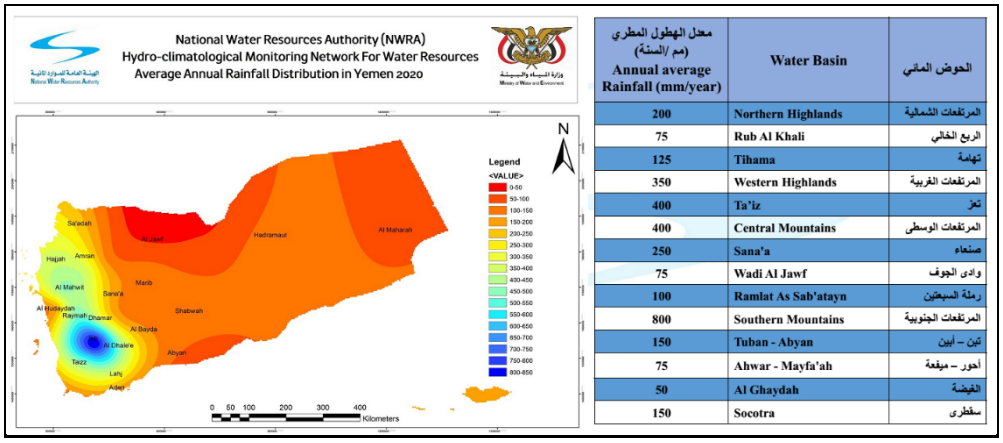
Overall, Yemen's surface water is distributed across four main drainage basins: the Red Sea, the Gulf of Aden, the Arabian Sea, and the Empty Quarter (Rub' al-Khali) (Figure 3). These basins are further divided into numerous valleys and sub-basins. The study area of the project includes major watersheds such as Wadi Hassan and Wadi Bana (Sarar and Lawdar districts), Wadi Ahwar (Ahwar and Al-Mahfad districts), and Wadi Mayfaʿah (Nisab district). All of these valleys drain into the Gulf of Aden, except for Wadi Khora and Wadi Bayhan (Markha Al-Sufla and Bayhan districts), which flow into the Empty Quarter. The study area falls under Watersheds 2 and 3 of Yemen's watershed system (see Figure 3).



Map 9: Location of the targeted districts within the main watershed in Yemen.

3..1 Surface water

In the project areas, improvements in terrace agriculture (e.g., in Sarar District) and increased upstream water diversion (e.g., in Bayhan and Ahwar) have altered hydrological dynamics. These practices have resulted in reduced base flows and less frequent spate events in several wadis, including Wadi Serar, Wadi Bayhan, and Wadi Ahwar. It is important to note, however, that this does not necessarily indicate higher water losses from the hydrological system. On the contrary, part of the diverted water may contribute to enhanced groundwater recharge through percolation, and upstream applications may in fact be more efficient in terms of water use productivity compared to downstream uses.



معدل الهطول المطري (مم /السنة) Annual average Rainfall (mm/year)	Water Basin	الحوض المائي
200	Northern Highlands	المرتفعات الشمالية
75	Rub Al Khali	الربع الخالي
125	Tihama	تهامة
350	Western Highlands	المرتفعات الغربية
400	Ta'iz	تعز
400	Central Mountains	المرتفعات الوسطى
250	Sana'a	صنعاء
75	Wadi Al Jawf	وادى الجوف
100	Ramlat As Sab'atayn	رملة السبعتين
800	Southern Mountains	المرتفعات الجنوبية
150	Tuban - Abyan	تبن – ابين
75	Ahwar - Mayfa'ah	أحور – ميفعة
50	Al Ghaydah	الغيضة
150	Socotra	سقطرى

Map 10: Spatial distribution of average annual rainfall in Yemen and the study area for 2020 (NWRA).

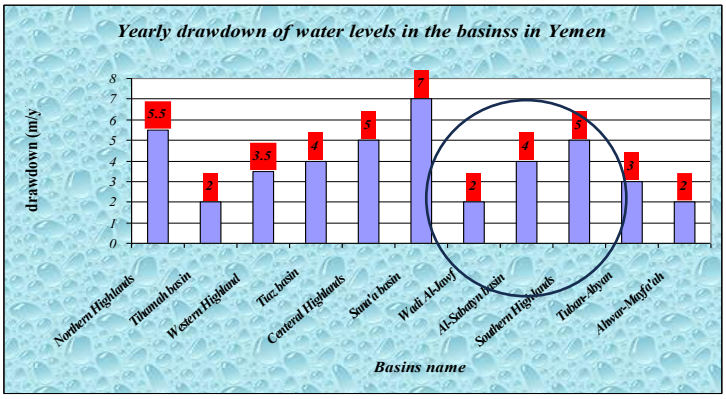


Figure 15:Yearly draw down of water level of the major wadis in Yemen (Targeted valleys within the demarcated circle)

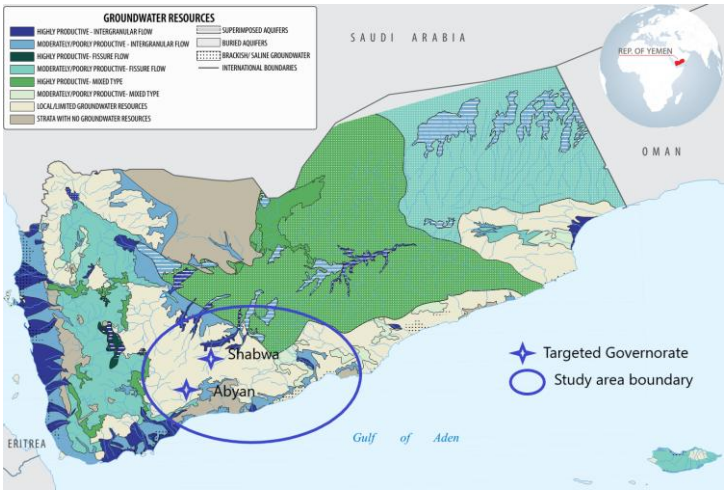
3..2 Groundwater

There are currently no recent groundwater assessments that provide updated data on aquifer reserves in Yemen. The country's major aquifer systems include Quaternary sedimentary aquifers, Quaternary alluvial aquifers, Tertiary volcanic aquifers, Cretaceous sandstone aquifers (Tawila/Mukalla formations), and Jurassic sandstone aquifers. The most productive systems are the Quaternary aquifers, located along the floors of major wadis in the southern and western coastal regions, and the sandy aquifers of the interior desert plains (Figure 6).

Within the project area, most districts are underlain by groundwater-bearing aquifers. An exception is Sarar District, where mountainous geology limits aquifer storage, and water is confined primarily to wadi alluvium deposits, which tend to dry up rapidly during the dry season. Figure 6 presents the distribution of Yemen's aquifer systems, including those underlying the study area.

Groundwater resources across the targeted districts are under severe stress due to over-abstraction and recurrent droughts. Groundwater levels are reported to be declining at an average rate of 3–6 meters per year

in northern valleys, while in the study areas of Wadi Ahwar (Abyan) and Wadi Mayfaʿah (Shabwa), the decline is estimated at 2–2.5 meters annually. This rapid depletion poses a critical threat to agricultural sustainability, water security, and rural livelihoods.



Map 11: Types of Groundwater aquifers in Yemen, including the study area.

3..3 Water Balance

Water use in Yemen significantly exceeds the availability of renewable resources. The country's annual renewable water resource is approximately 2.5 BCM, of which about 60 percent originates from groundwater and the remainder from surface water. In 2010, annual water use was estimated at 3.9 BCM, creating an annual deficit of 1.4 BCM (MAI, 2013). By 2020, total water use had increased to an estimated 5.1 BCM, representing a 76 percent rise since 1990.

This rapid growth has been driven largely by the agricultural sector, which continues to account for around 80 percent of total water use, while domestic and industrial uses—although still only about 20 percent—have increased more than tenfold over the past three decades (CES, 2008; UN ESCWA, 2015).

The widening gap between water supply and demand is being met primarily through the over-abstraction of fossil (non-renewable) groundwater. As a result, the national annual water deficit is estimated at around 261 MCM, while groundwater tables are declining at an alarming rate of 2–4 meters per year, with pumping depths now exceeding 1,000 meters in many areas (UNDP, 2022).

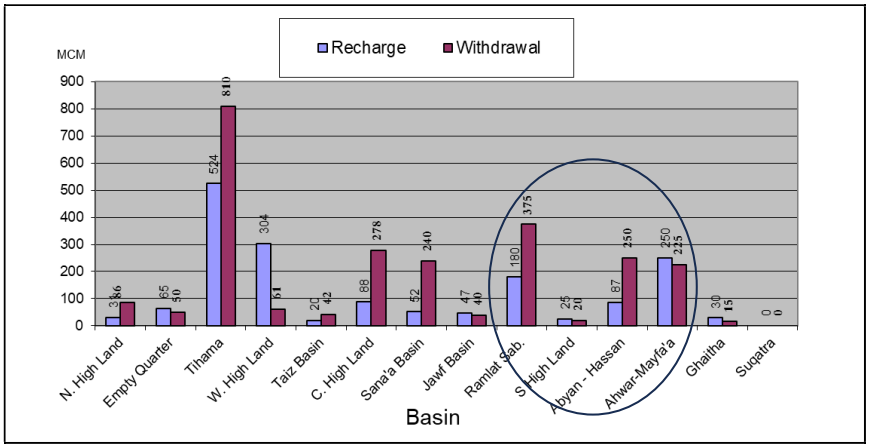


Figure 16: Water balance deficit in main wadis in Yemen (Targeted Wadis within the demarcated circle)

6.1 Water Infrastructure and key challenges and vulnerabilities

3..1 Shabwah Governorate

The water supply and agricultural systems in Shabwa are overwhelmingly dependent on groundwater abstraction from shallow and deep wells, which serve as the main source of both drinking water and irrigation. Pumping remains dominated by diesel-powered generators, leaving communities vulnerable to fluctuating fuel prices and chronic shortages. In recent years, solar pumping systems have been introduced in rural water projects as a more sustainable alternative; however, their coverage is still limited compared to the governorate's overall demand. Water storage infrastructure in towns and larger villages consists of elevated tanks, yet their capacity is inadequate to cope with prolonged droughts or peak summer consumption. In rural areas, households supplement water supply through traditional cisterns and ponds, but most are poorly maintained, heavily silted, or damaged, which limits their effectiveness in enhancing water security during dry periods.

Agriculture is centered on traditional spate irrigation systems, particularly in Wadi Markha and Wadi Bayhan, where seasonal floods are channeled through earthen canals, diversion structures, and embankments. Historically, these systems supported extensive cultivation, but they are now severely degraded due to sediment buildup, recurrent flood damage, and lack of maintenance. Their declining functionality means that less water reaches farmlands, while uncontrolled runoff frequently destroys crops and strips soil. Adoption of modern irrigation methods and small-scale pumping systems is minimal, leaving farmers reliant on fragile and outdated practices. In addition, beekeeping—especially the production of Shabwa's renowned Sidr honey—represents a valuable livelihood, yet it has been undermined by vegetation loss, prolonged droughts, and land degradation, threatening one of the governorate's most important value chains.

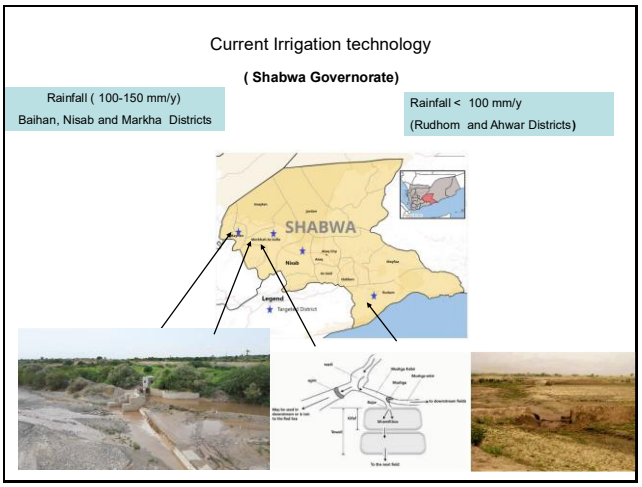


Figure 17: Example of Irrigation practices applied in the study area across Shabwa

Wastewater and sanitation infrastructure are almost entirely absent. The Nisab wastewater treatment plant is non-functional, and untreated wastewater is discharged into wadis or soak pits, contributing to contamination of shallow aquifers that already face heavy stress. This situation becomes particularly critical during

droughts, when communities rely more on shallow wells for drinking water. At the same time, flood protection and watershed management structures—including diversion weirs, embankments, and recharge barriers—are in disrepair or collapsed. The lack of functional recharge dams and aquifer replenishment systems means that most seasonal runoff is lost through destructive flash floods rather than contributing to groundwater recharge.

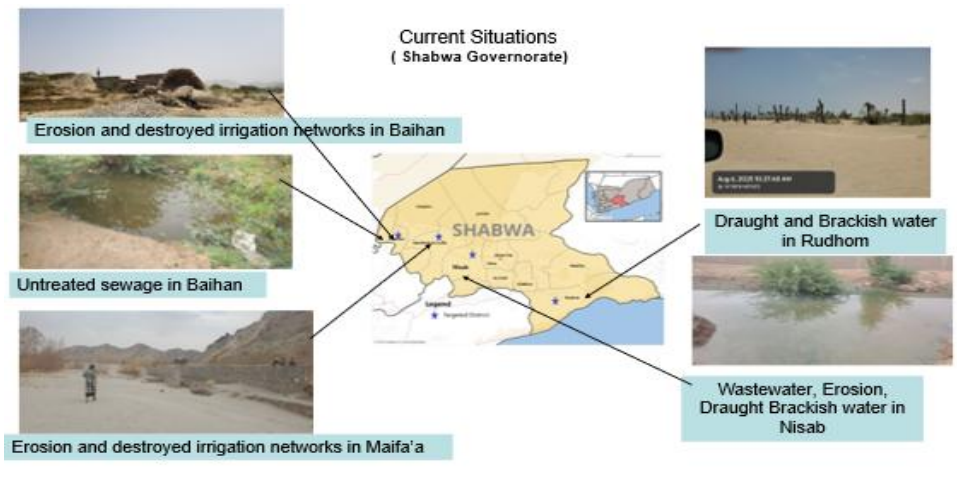


Figure 18: Examples of key environmental challenges (a), and damage due to the floods in Bayhan

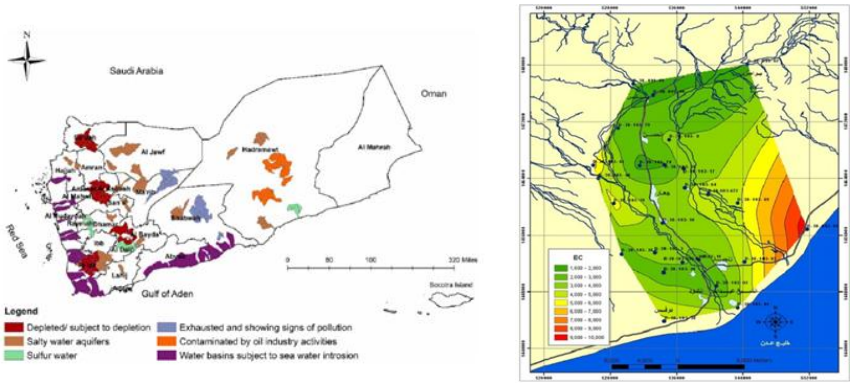
Climate extremes further aggravate pressures: the August 2025 floods in Bayhan and Markha destroyed terraces, irrigation canals, and recharge barriers, while stripping fertile topsoil without effectively recharging aquifers. By contrast, prolonged droughts reduce recharge opportunities, weaken rangelands, and increase soil fragility, which makes subsequent flash floods more destructive.



Figure 19: Damage due to the floods in Bayhan, 2025

Water quality challenges are severe in both coastal and inland districts. Since 2015, the spread of illegal well drilling without geological assessments has led to failed wells, wasted financial resources, and community

disputes. In Rudhom District, seawater intrusion combined with geological salinization has caused sharp deterioration of groundwater quality; in Bir Ali, electrical conductivity has reached 8,000 µS/cm, far exceeding safe thresholds for irrigation and drinking.

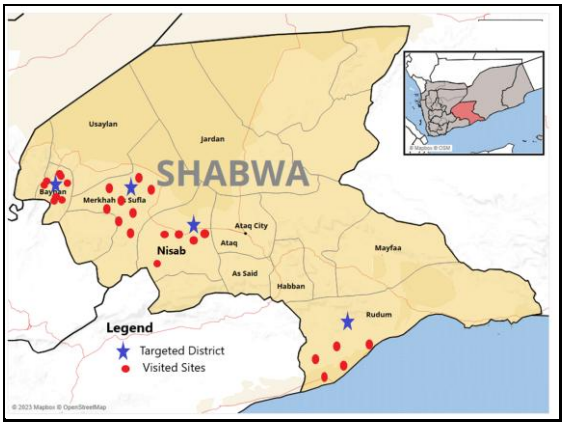


Map12 : Saline GW (Brackish water) aquifers across the country and Shabwah and Radhoum

The combined effect of degraded infrastructure, declining aquifers, saline intrusion, and intensifying climate extremes poses severe risks to agriculture, livestock, and household water security. Crop yields are falling, livestock mortality is rising, and the collapse of Sidr honey production is undermining rural income. These pressures have heightened household vulnerability to food insecurity and livelihood loss, underscoring the urgent need for climate-resilient water systems, modernized irrigation, aquifer recharge interventions, and livelihood diversification to stabilize Shabwa's rural economy.

3..2 Key Challenges at the district level

Field visits to the targeted districts of Shabwa revealed a complex set of environmental and social challenges that directly shape local development priorities (see Figure X). These visits provided concrete evidence of how climate change, resource degradation, and weak infrastructure intersect to impact communities, highlighting issues such as declining groundwater reserves, deteriorating spate irrigation systems, recurrent flood damage, soil erosion, and reduced agricultural productivity. Social vulnerabilities were equally evident, with households facing food insecurity, declining livelihoods such as Sidr honey production, and limited access to safe water. The documentation of these conditions substantiates the climate rationale for proposed interventions and ensures that response measures are designed in alignment with community priorities, offering a clear framework for addressing gaps and building long-term resilience across Shabwa's districts.



Map 13: Saline GW (Brackish water) aquifers across the country and Shabwah and Radhoum

3..2.1 Nisab District

The main environmental and climate challenges in Nisab district can be summarized and prioritized as follows:

- **Sanitation deficiencies**: The lack of functional wastewater treatment facilities results in the discharge of untreated wastewater into open drains, contaminating the shallow aquifer. During drought periods, when safe water becomes scarce, contamination risks intensify as households rely more heavily on shallow wells. Farmers, facing acute water shortages for irrigation and livestock, are often forced to use untreated wastewater or polluted sources to keep crops alive and provide fodder for animals. This practice helps to delay land degradation and desertification but creates serious risks to public health, food safety, and ecosystem integrity.

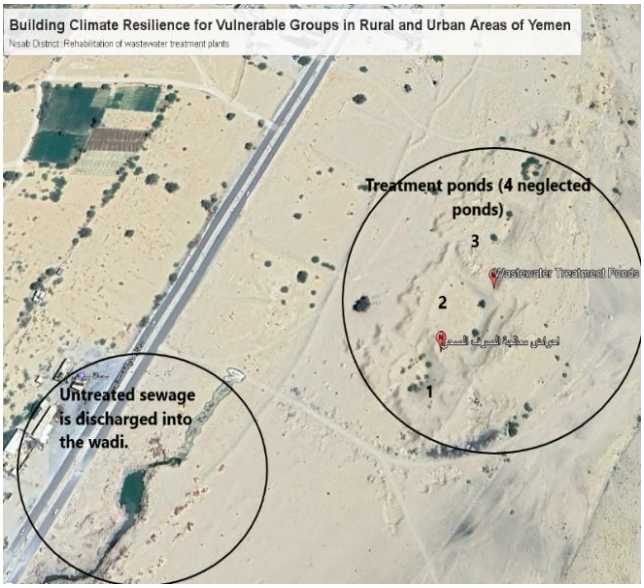


Figure X:



Figure20 : Wastewater Sanitation Plant condition and untreated water

- **Inadequate drinking water storage:** The small number and low capacity of storage tanks, coupled with weak maintenance, limit the availability of safe water during dry seasons, increasing household vulnerability to shortages.



Figure 21:Unfunctional water storage

- **Saline groundwater:** Excessive pumping, drought and water scarcity, poor recharge, and natural geological salinity have degraded water quality with total dissolved solids (TDS) ranging between 5,000 and 7,000 mg/L., reducing its usability for agriculture and drinking.



Figure 22:Example of Brackish water in Nisab districts pumping water for almost 300 families

- **Flood-related damage and land degradation:** Intense flash floods cause severe soil erosion, strip away fertile topsoil, and accelerate the deterioration of irrigation infrastructure such as canals and diversion weirs. The resulting land degradation reduces agricultural productivity, increases runoff, and makes farmland more vulnerable to desertification.



Figure23 :Irrigation canal damaged by floods and soil erosion

- **Drought**

stress: Persistent low rainfall, high evaporation rates, and inadequate water harvesting capacity intensify water scarcity. Overuse of available water resources to meet immediate needs further lowers aquifers, reduces agricultural productivity, and places livelihoods under severe strain.



Figure24 :Example of drought in Nisab Districts

3..2.2 Markha Asufla

The main environmental and climate challenges in Markha Asufla District can be summarized and prioritized as follows:

- **Erosion of wadi banks and irrigation infrastructure:** Frequent flash floods erode agricultural wadi banks and damage irrigation canals, diversion structures, and related infrastructure, reducing the efficiency of spate irrigation and threatening farmland productivity.



(a)





(b). (c)

Figure25 :Land degradation, soil erosion and irrigation canal damage due to the flash floods

- **Recurrent drought and desertification:** Prolonged drought conditions, combined with limited rainfall and high evaporation rates, are accelerating land degradation and driving progressive desertification, which undermines both crop and livestock systems.
- **Insufficient drinking water storage:** The district suffers from inadequate storage capacity for potable water, with too few tanks and poor maintenance, leaving communities vulnerable to shortages during dry periods. As seen in the figure X, the Al-Hajr city where more than 40% of the population don't have excess to the water due to the limited storage system which enforce the people and families to depend on water tracking with high cost up to USD 20 for 6000 L which affects the families incomes and livelihoods.

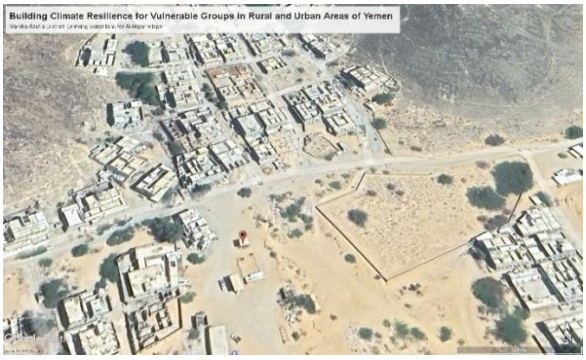


Figure 26:Example of limited water storage in Al-Hajr City (One water storage for the city)

3..2.3 3. Bayhan District

The main environmental and climate challenges in Baihan District can be summarized and prioritized as follows:

- **Sanitation issues:** The absence of wastewater treatment systems results in untreated effluent being discharged into wadies and soak pits, contaminating shallow aquifers. During droughts, when reliance on shallow wells increases, contamination risks rise significantly. This situation forces some households and farmers to use unsafe water for irrigation and livestock, exposing communities to serious public health threats and long-term soil and water degradation.



Figure 27:Untreated water in the wadi used for agriculture purposes during the drought seasons





- **Erosion of wadi banks and irrigation infrastructure:** Seasonal flash floods cause widespread erosion along agricultural wadis, washing away fertile soils and damaging traditional irrigation infrastructure such

as diversion canals and earthen embankments. This not only reduces water distribution efficiency but also accelerates land degradation and undermines crop productivity.

(a) (b)

(c)



Figure28 :Soil erosion and irrigation canals damage due to flash floods



Figure29 :Example of damaged sidr trees due to extreme drought

- **Persistent drought and desertification:** Recurrent drought conditions, coupled with high evaporation and limited groundwater recharge, have intensified water scarcity. Agricultural land is increasingly exposed to desertification, while rangelands lose vegetation cover, reducing fodder availability and threatening livestock-based livelihoods.

3..2.4 Rudhom District

The main **environmental and climate challenges** in Rudhom District can be summarized and prioritized as follows:

- **Saline Groundwater:** Groundwater resources have been severely degraded due to saline water intrusion driven by sea-level rise, excessive abstraction, limited aquifer recharge, and adverse geological conditions. Salinity levels are particularly acute, with total dissolved solids (TDS) ranging between 6,000 and 8,000

mg/L—far above safe thresholds for both drinking and agricultural use. Consequently, households are increasingly dependent on costly water trucking, paying between USD 1–2 per liter, which places a heavy financial burden on communities and directly undermines food security and livelihoods.

- **Drought conditions:** Recurrent low rainfall, high evaporation, and intensive groundwater pumping have led to chronic water scarcity. Irrigated agriculture is in decline, while grazing areas are shrinking, reducing the availability of livestock fodder and undermining pastoral systems.



Figure30 :Draught in Radhum villages

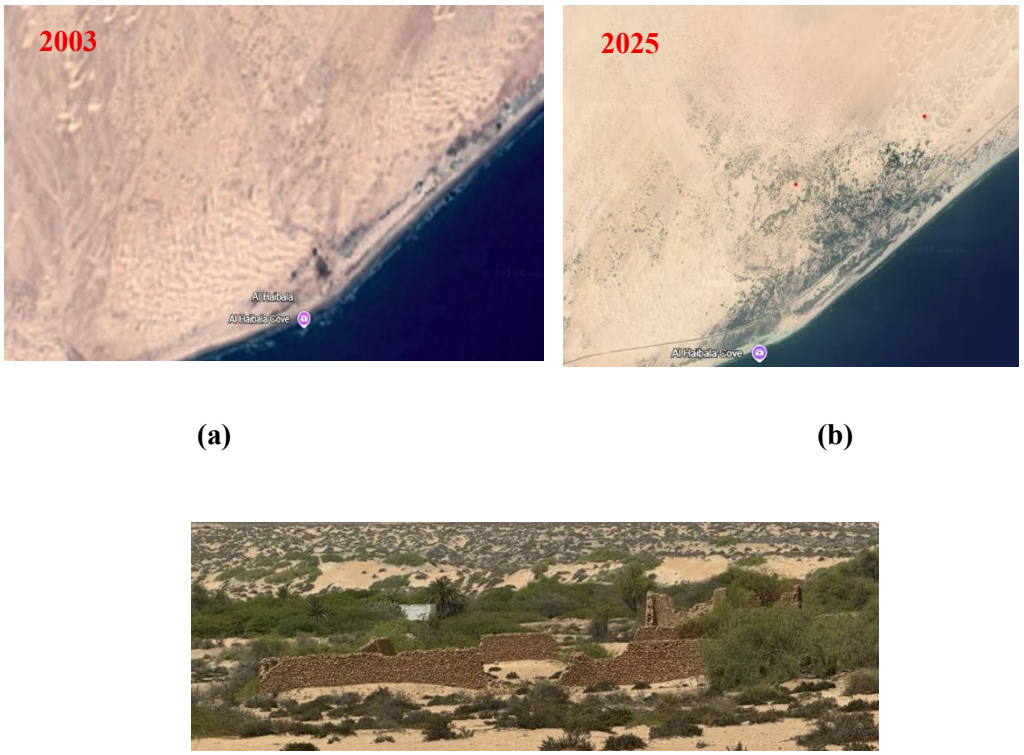
- **Desertification and sandstorms:** Advancing desertification, driven by prolonged droughts and vegetation loss, has made the district highly vulnerable to sandstorms. These storms bury agricultural plots, damage rural infrastructure, accelerate soil degradation, and contribute to land abandonment and migration pressures.



Figure 31:Damage of palm dates due to desertification and sandstorms

- **Spread of Mesquite:** The uncontrolled spread of invasive Mesquite trees across wadis and agricultural lands has become a major environmental concern. Their deep root systems compete aggressively for groundwater, further depleting aquifers and reducing water available for crops and domestic use. By obstructing natural stormwater drainage, mesquite thickets increase localized flooding, erode wadi banks,

and disrupt watershed functions. In addition, mesquite invades farmland and competes with traditional crops such as date palms, reducing yields and undermining one of the region's most important value chains. Its rapid spread accelerates land degradation and significantly raises the cost of farm rehabilitation.



(a) **(b)**

(C)

Figure32 :Spread of Mesquite between 2003 (a), and (2023), and its impact on the ecosystems lower functionality (c)

Table 30:Summary of the impacts of the water systems' vulnerability and challenges in the targeted districts of Shabwah

Challenges & Vulnerabilities	Districts	Socioeconomic Impacts	Ecosystem Impacts	Public Health Impacts
Sanitation deficiencies (untreated wastewater)	Nisab, Baihan	15–20% of households forced to buy bottled water or trucked water due to the threats of the water contamination; farmers increasingly irrigate with untreated wastewater, reducing farm income by ~25%.	Contamination of shallow aquifers and wadies in drought seasons particularly, degradation of soils.	Higher prevalence of diarrheal diseases; cholera and typhoid risks increase during droughts.
Limited drinking water storage	Nisab, Markha Asufla	Women/children spend 2–3 extra hours/day fetching water; in Al-Hajr (Markha), 40% of population lacks access and pays up to USD 20 per 6,000 L, consuming 10–15% of monthly income.	Less water for livestock and native vegetation, loss of rangeland resilience.	Water scarcity increases dehydration risks; exposure to unsafe water raises disease burden.
Saline groundwater (TDS 5,000–8,000 mg/L)	Nisab(4,000–6,000), Rudhom (6,000–8,000)	Up to 25% decline in farm income due to abandonment of irrigated crops; increased reliance on costly water trucking (USD 1–2/L in Rudhom).	Soil salinization reduces fertility, damages date palms, reduces vegetation cover.	Consumption linked to kidney stress and hypertension; long-term reliance increases health risks
Erosion of wadi banks & damaged irrigation canals	All districts	Farmers lose 3% to 5% of cultivable land annually; reduced yields cut local household income by ~30%.	Sedimentation degrades wetlands, reduces riparian vegetation.	Reduced nutrition from declining food production.
Drought stress (low rainfall, high evaporation, poor recharge)	All districts	Crop yields down by 30–40%; fodder shortages raise livestock mortality by 15–20%; household debt rises after drought years.	Vegetation loss accelerates desertification; soils become less absorptive and more prone to erosion.	Malnutrition rises as food availability declines; heat stress worsens in vulnerable groups.
Desertification & sandstorms	Rudhom, Baihan, Markha Asufla	Land abandonment affects 10–15% of farms; sandstorm damage reduces date yields by 30–40%; migration pressures increase.	Sand burial of farmland, palm tree damage, soil fertility decline.	Respiratory illnesses increase during sandstorms, especially in children and elderly.
Flood-related soil erosion & land degradation	All districts	Soil erosion causes 20–25% loss of fertile topsoil over 10 years; repeated infrastructure repairs cost 5–10% of local household budgets.	Flash floods destroy terraces, recharge barriers, and irrigation canals.	Standing floodwaters raise risk of vector-borne diseases (malaria, dengue).
Drought-damaged Sidr trees (honey production)	Baihan, Nisab	Sidr honey production down by 40–50% in drought years; loss of a high-value product reduces household cash income by up to USD 600–900 per family/year.	Loss of pollinator habitats and biodiversity; reduced soil stability.	Loss of traditional nutrition and medicinal honey.

Spread of Mesquite	Rudhom (major), also spreading to others	Invades farmland, reduces date palm yields by 20–25%; costly removal increases farm rehabilitation costs by ~USD 150–200/ha.	Disrupts natural stormwater drainage depletes aquifers; increases wadi erosion.	Reduced water availability raises indirect health risks from unsafe water reliance.

3..3 Abyan Governorate

The water supply and agricultural systems in Abyan rely heavily on groundwater from shallow and deep wells, with pumping still dominated by diesel but increasingly supplemented by solar in rural areas. Storage capacity is limited, while traditional cisterns and ponds are poorly maintained. Agriculture depends mainly on spate irrigation networks in Wadi Ahwar, Wadi Bana, and Wadi Hassan, but these systems are deteriorating due to floods, siltation, and lack of upkeep. Terraced farming in the uplands has also declined, and the absence of adequate post-harvest facilities and modern irrigation further weakens farming systems.

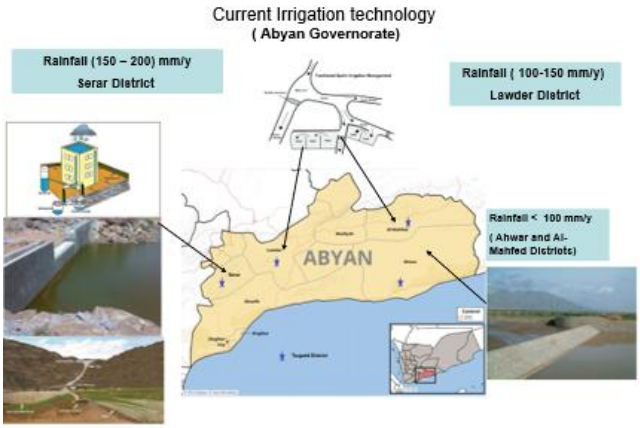


Figure 33:Example of Irrigation practices applied in the study area across Abyan governorate

Wastewater treatment and flood protection infrastructure are mostly absent or non-functional, while recharged dams are lacking, accelerating groundwater decline. Water quality problems, particularly salinity in coastal and transitional areas like Ahwar and Al-Mahfad, reduce both domestic and agricultural usability. Unregulated well drilling, combined with droughts, flash floods, and land degradation, has intensified competition over scarce resources. These pressures undermine agricultural production, reduce livestock herds, and heighten household vulnerability to food insecurity, loss of income, and displacement.

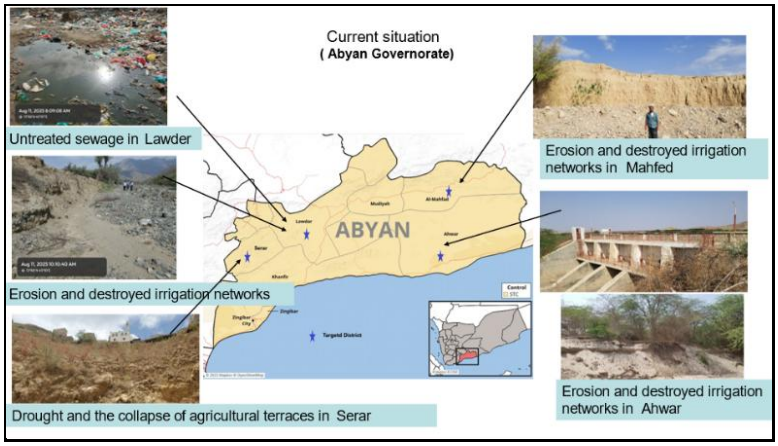
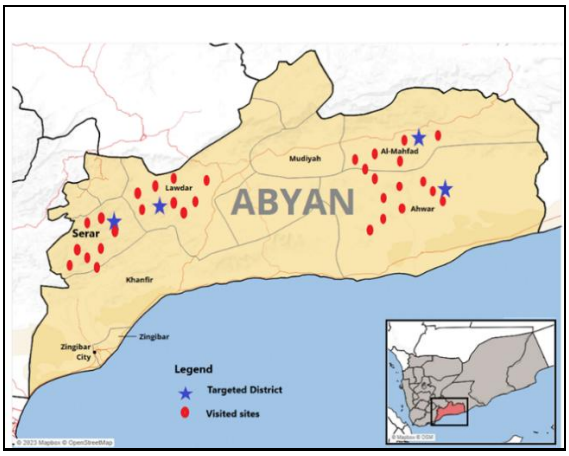


Figure 34:Examples of key environmental challenges at selected districts

3..4 Key Challenges at the district level

Field visits to the targeted districts of Abyan revealed critical environmental and social challenges (see Figure X). The governorate faces challenges in the treatment of wastewater, , recurrent droughts, deteriorating spate irrigation infrastructure, and the collapse of terraces in upland areas. In the coastal plains, flooding and advancing desertification further threaten farmland and rural settlements. These pressures, combined with limited water storage, poor sanitation, and the absence of wastewater treatment, increase food insecurity, reduce household incomes, and heighten vulnerability to displacement.



Map 14:Visited sites in Abyan targeted districts

3..4.1 Ahwar District

Ahwar District serves as the core of the Delta of Ahwar, a crucial drainage area where wadis converge before flowing into the Gulf of Aden. Positioned within this catchment, Ahwar plays a vital role in local

hydrology, capturing seasonal floodwaters that sustain agriculture and replenish groundwater reserves. The delta relies on spate irrigation, with roughly 80% of cropped land watered by seasonal floods; the remainder depends on wells or a combination of floodwater and groundwater



Map 15:Ahwar Delta

The district faces several interlinked environmental and climate challenges:

- **Erosion of irrigation systems:** Recurrent flash floods erode wadi banks and damage traditional spate irrigation canals and diversion structures, reducing their efficiency and limiting water distribution to farmland.





Figure 35:Examples of key irrigation canals damage and erosion challenges in Ahwar Destrict

- **Drought stress:** Low and irregular rainfall, combined with high evaporation rates and limited water harvesting capacity, have intensified water scarcity. Over-abstraction of groundwater further reduces agricultural productivity and undermines rangeland resilience.
- **Insufficient drinking water storage:** The district suffers from a shortage of functional storage tanks, and those that exist are often poorly maintained. This limits the availability of safe drinking water during dry seasons, increasing household vulnerability and dependence on costly alternatives such as water trucking.

1. Al-Mahfed District

The main environmental and climate challenges in Al-Mahfed District can be summarized and prioritized as follows:

- **Inadequate drinking water storage:** The district has too few storage tanks, most of which are small and poorly maintained. This limits household access to safe water during dry periods and increases dependence on costly or unsafe alternatives.
- **Saline groundwater:** Excessive pumping, combined with limited recharge and unfavorable geological conditions, has resulted in high salinity levels that compromise groundwater quality. This reduces its suitability for both drinking and irrigation and forces farmers to abandon or reduce cultivation.
- **Flood-related erosion:** Seasonal flash floods frequently erode wadi banks and damage irrigation canals, diversion structures, and farmland. The deterioration of irrigation infrastructure undermines spate irrigation efficiency and accelerates land degradation.



Figure 36:Soil Erosion example in Almahfd

- **Drought stress:** Low and irregular rainfall, coupled with high evaporation rates and limited water harvesting capacity, exacerbates water scarcity. Overuse of groundwater resources has deepened aquifer depletion, reduced agricultural productivity, and weakened rangeland systems.

3..4.2 Lawder District

Lawder District has experienced a rise in population and displacement inflows, which has significantly increased pressure on already fragile water and sanitation services. Existing systems are unable to meet the growing demand, leaving communities more vulnerable to shortages, contamination, and health risks.

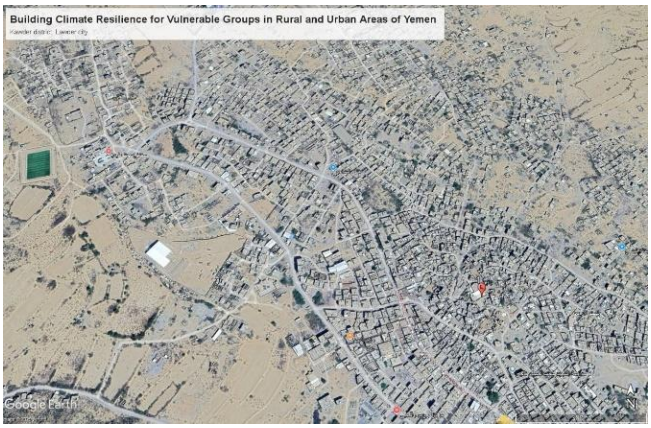


Figure 37:Lowder city

The main environmental and climate challenges in Lawder District can be summarized and prioritized as follows:

- **Sanitation problems:** The absence of a functional wastewater treatment plant has resulted in untreated sewage being discharged into open drains and wadies. This has contaminated shallow aquifers, which are heavily relied upon for drinking water. During droughts, when reliance on these sources increases, the risks of contamination and waterborne disease outbreaks become much higher.





Figure38 :Sanitation ponds in Lowder City

- **Inadequate drinking water storage**: The district suffers from a shortage of storage tanks, and many of the existing facilities are too small or poorly maintained. This limits reliable access to safe water during dry periods and forces households to depend on costly water trucking.
- **Flood-related erosion:** Flash floods frequently erode agricultural land and damage traditional irrigation infrastructure, including diversion structures and canals, reducing irrigation efficiency and accelerating land degradation.



Figure39 :Erosion and Irrigation facilities damaged by floods

- **Drought stress:** ow and irregular rainfall, combined with high evaporation and limited water harvesting systems, has deepened water scarcity. Over-reliance on groundwater abstraction has accelerated aquifer depletion. In the **last two years**, agricultural production has **declined by about 30% due to drought conditions**, leading to reduced food availability, lower household incomes, and growing livelihood insecurity.



Figure40 :Agricultural lands during the drought

3..4.3 Sarar District

The main environmental and climate challenges in Sarar District can be summarized and prioritized as follows:

- **Drought stress:** Persistent low rainfall, high evaporation, and limited water harvesting capacity have deepened water scarcity. Overuse of groundwater has reduced aquifer levels and weakened rangeland systems. Drought has been particularly devastating for coffee production, which has declined by nearly 80% over the past four years, threatening one of the district's most important cash crops and income sources.



Figure41 :Crops failure due to extreme draught

- **Water pollution:** The discharge of untreated wastewater into Wadi Sarar and Wadi Hatat has contaminated groundwater sources, creating serious health risks. This has increased the incidence of waterborne diseases and undermined confidence in local water supplies.
- **Inadequate drinking water storage:** The district has too few storage tanks, and existing facilities lack the capacity to provide reliable water access during drought periods, forcing households to rely on unsafe sources or costly water trucking, which in some locations cost up to USD 150 for 6000 L.
- **Terrace erosion:** Agricultural terraces in upland areas have been severely damaged by flash floods. The collapse of these structures reduces soil retention, accelerates erosion, and decreases the ability of farms to capture and use rainfall effectively.



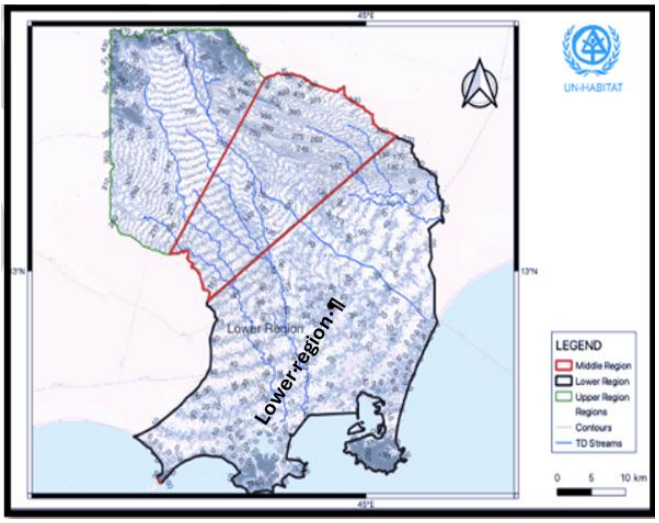
Figure42 :Collapse of agricultural terraces

Table X: Summary of the Key Environmental and Climate Challenges in Abyan Districts and their impacts

Challenges & Vulnerabilities	Districts	Socioeconomic Impacts	Ecosystem Impacts	Public Health Impacts
Erosion of irrigation systems / terraces	All four districts	Farmers lose ~5–7% of farmland per year; repeated repairs increase household costs by 10–15%. In Sarar, terrace collapse reduces household crop output by ~20%.	Loss of fertile topsoil, reduced water retention, and downstream siltation degrade wetlands and riparian habitats.	Lower food availability worsens nutrition; standing floodwater raises vector-borne disease risks (malaria, dengue).
Drought stress and water scarcity	All four districts	Crop yields have declined by 30% in Lawder in the last two years; coffee in Sarar fell by 80% over four years. Livestock losses reach 15–20%. Household debt rises in drought years.	Vegetation cover loss accelerates desertification; rangeland degradation reduces fodder supply.	Food insecurity increases; heat stress and malnutrition risks grow for vulnerable groups.
Inadequate drinking water storage	All four districts	Up to 40% of households lack reliable supply in peak dry seasons; trucking costs up to USD 150 per 6,000 L in Sarar. Women/children spend an extra 2–3 hours/day fetching water.	Reduced water availability for livestock and natural vegetation.	Reliance on unsafe sources increases diarrheal disease burden.
Saline groundwater	Al-Mahfed, coastal Ahwar	High salinity reduces irrigation reliability and forces abandonment of high-value crops. Farm income losses estimated at 20–25%.	Soil salinization depletes fertility; reduces resilience of date palms and coastal crops.	Saline water consumption is linked to hypertension and kidney stress.
Sanitation and wastewater pollution	Lawder, Sarar	Families spend more on bottled/trucked water; in Sarar, unsafe water use lowers productivity and raises treatment costs.	Contamination of wadis and shallow aquifers disrupts aquatic habitats.	Sharp increase in waterborne disease outbreaks (diarrhea, cholera, typhoid). In the last five years, the outbreak of cholera in Lowder
Flood-related erosion and infrastructure damage	Ahwar, Al-Mahfed, Lawder, Sarar	Irrigation canals and roads damaged every flood season; repair costs consume ~5–15% of local budgets.	Sediment loads degrade downstream ecosystems and alter floodplain functions.	Disrupted services increase exposure to unsafe water and food shortages.

3..5 Aden Governorate

The Tuban Delta is the primary water source for Aden and one of Yemen's most important groundwater basins, extending over nearly 2,000 km² and supporting both the urban population of Aden and around 9,200 hectares of irrigated agriculture in the Lahej plain. Historically, the delta provided a reliable lifeline, recharged by rainfall and spate flows from the highlands, but decades of over-abstraction, declining recharge, and the intensifying effects of climate change have pushed the system into crisis. Aden depends almost entirely on this aquifer, yet its renewable supply is now limited to about 53 million cubic meters (MCM) annually, far below the current demand of 136.4 MCM. Of this demand, 45.5 MCM is needed for domestic use while nearly 92 MCM is consumed by agriculture. This leaves the city and its surrounding delta with a staggering deficit of 84.4 MCM each year, meaning that less than 40 percent of water demand is actually met. Projections show that this shortfall will widen to 90 MCM by 2025 and could reach 147 MCM by 2050, effectively tripling demand compared to what the aquifer can sustainably provide.



Map 16:Tuban Delta including Aden

The stresses on the Tuban Delta are compounded by rapid groundwater drawdown and seawater intrusion. In some parts of the basin, groundwater tables are falling by 2–4 meters annually, while in the coastal zones salinity levels have reached between 5,000 and 8,000 mg/L of total dissolved solids, well above safe thresholds for both drinking and irrigation. As wells dry up or turn saline, households are increasingly forced to rely on expensive water trucking or unsafe private sources, often paying 10–20 percent of their income for water. Agriculture in the Lahej plain is similarly threatened, with soil salinization and declining yields already forcing reductions in cultivated area. Without intervention, more than half of current farmland in the Tuban Delta could become non-viable by 2050. Climate change is expected to deepen this crisis: rising temperatures of up to 3.5–4°C by the end of the century will drive up evapotranspiration, rainfall variability will add 8–14 additional dry days each year, and sea-level rise of 30 cm by mid-century will push saltwater intrusion further inland. At the same time, flash floods are becoming more intense, destroying infrastructure and eroding soils rather than recharging aquifers.

For Aden, the implications are severe. The city's near-total dependence on the Tuban Delta means that the deficit translates directly into unreliable water supply, high costs for households, food insecurity, and growing health risks. Up to a quarter of households are not even connected to the water grid, and for those who are, service is highly irregular. In drought periods, families fall back on brackish or bacteriologically contaminated wells, driving up incidences of cholera, diarrhea, and kidney illnesses. The depletion of groundwater has also disrupted ecosystem flows, with little water now reaching the coast, accelerating land degradation and biodiversity loss. With renewable water unable to cover even half of demand, and the deficit projected to nearly triple by mid-century, Aden cannot rely on its aquifers alone. The scale of this gap underscores the urgent need for decentralized desalination units as the only viable long-term solution to secure safe, reliable water for the city, reduce pressure on the Tuban Delta, and protect both livelihoods and ecosystems.

3..6 Al-Hudaydah

Al-Hudaydah, located along Yemen's Red Sea coast, is one of the most climate-vulnerable and water-stressed governorates in the country. The governorate's low-lying coastal plains and dense population make it highly exposed to both seawater intrusion and groundwater depletion, while its water and sanitation infrastructure has suffered from years of neglect and conflict. Population growth, large numbers of displaced people, and unregulated water extraction have intensified pressure on already scarce water resources. The project intervention targets highlights critical challenges in Al-Khokhah and Hays districts, where a combination of salinity, contamination, and the absence of wastewater networks has created a severe water crisis that undermines public health, livelihoods, and environmental sustainability.

3..7 Key challenges and vulnerability on District level

3..7.1 Al-Khokhah District

Al-Khokhah hosts more than 60,000 people, half from the host community and half displaced from other districts. Water is mainly drawn from shallow wells, of which there are more than 3,000 across the district. Depths range from 6–15 meters, becoming deeper eastwards away from the sea. Originally these wells provided fresh, clean water, but over the past years they have been heavily degraded by salinity and contamination. Climate change, particularly declining rainfall and recurrent droughts, has accelerated seawater intrusion into aquifers. Over-extraction for agriculture, especially water-intensive crops like onions—has lowered water tables to depths of around 110 meters in the eastern parts of the district, which in turn allows seawater to encroach inland. Surveys revealed that around 60% of the wells in Al-Khokhah are now saline.

Contamination compounds this crisis. The city lacks a sewerage network, and wastewater disposal relies on cesspits and septic tanks located only 2–5 meters from drinking water wells. Due to population density and limited space, safe distances are not maintained, resulting in biological pollution (E. coli) of many drinking water sources. Without safe sanitation, wastewater and stagnant water accumulate in streets, aggravating contamination. Health impacts are widespread: diarrheal diseases, malnutrition, typhoid, cholera, malaria, and dengue fever have been reported, with women and children most affected. Despite these risks, 40% of the population continues to use contaminated wells for drinking, cooking, and even for washing vegetables and ice blocks.

3..7.2 Hays District

Hays has a population of about 35,000, of whom 70% are displaced people from neighboring governorates, mainly Taiz. Water supply relies on more than 2,000 shallow wells at depths of around 60 meters. However, a critical disaster occurred roughly 35 years ago when many households, unaware of the consequences, converted their domestic wells into cesspits for wastewater disposal. This practice contaminated the aquifer that feeds both Hays and Al-Khokhah, covering an area of about 400 km². Laboratory tests of wells within and around the town showed widespread E. coli contamination of drinking water.

The situation is worsened by the absence of a functional sewerage network, leading to wastewater pooling in streets and neighborhoods, creating breeding grounds for mosquitoes and pathogens. Health data from hospitals confirm high incidence of typhoid, amoebiasis, acute diarrhea, and repeated outbreaks of cholera. Stagnant wastewater in streets also drives malaria and dengue transmission. This contamination undermines the aquifer's role as the main source of safe water for the city and surrounding rural communities, directly threatening food security and household resilience**.**

6.1 Priority interventions

The MCA process for Shabwa and Abyan involved consultations with stakeholders, experts, and community representatives, integrating climate rationale, socioeconomic priorities, and feasibility. Proposed measures focus on water harvesting and irrigation techniques suited to local climatic risks (Figure 34).

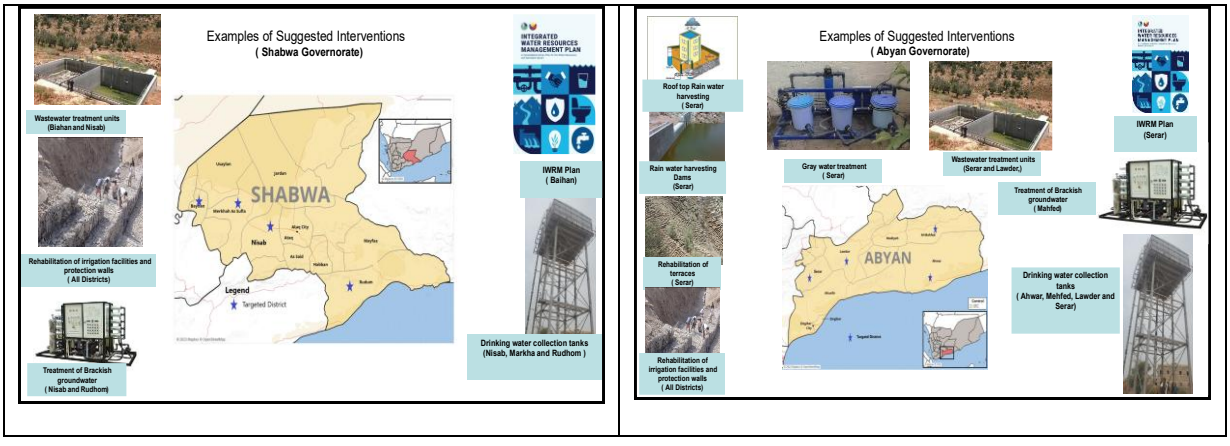


Figure43 :suggested interventions in the selected districts in Shabwa and Abyan Governorates

These interventions provide a comprehensive package to enhance resilience, improve water security, and protect livelihoods. Selection was guided by each district's climatic zone, ensuring tailored responses to droughts, floods, and temperature extremes.

3..1 Intervention on District level

3..1.1 Shabwah

Table 31:list of suggested interventions in all districts of Shabwah

Intervention Category	Districts	Intervention / Project Output	Description	Climate Rationale
Wastewater Management & Sanitation	Nisab, Bayhan	Rehabilitation of existing WWTP (Nisab); Small WWTP/septic unit (Bayhan); Wastewater quality testing; Awareness on safe reuse **(Outputs 1.2, 1.4)**	Rehabilitation or construction of treatment facilities, testing water quality, and promoting safe irrigation reuse.	Reduces contamination of shallow aquifers, protects public health, and ensures safe water reuse for irrigation, reforestation, ecosystem restoration during droughts.
Water Quality & Salinity Management	Nisab, Rudhom	Brackish water treatment units (Nisab–Saqam, Rudhom–Bir Ali); Awareness campaigns on source protection; Training on desalination **(Outputs 1.2, 1.4)**	Installation of desalination/treatment systems with capacity of (200 – 400 m^3day) and awareness on sustainable management.	Ensures access to safe drinking and irrigation water in areas where salinity (TDS 5,000–8,000 mg/L) threatens agriculture, food security, and health.
Water Storage & Supply	Nisab, Markha Asufla, Bayhan	Expansion/rehabilitation of diversion barriers, water storage system; Awareness of sustainable use of water**(Output 1.3)**	Build/rehabilitate large-capacity storage facilities to secure reliable water access.	Increases resilience to droughts, reduces reliance on costly water trucking, and safeguards vulnerable households and displaced populations.
Land Degradation & Desertification Control	Nisab, Markha Asufla, Bayhan, Rudhom	Spatial planning for land use; Erosion control works (wadis: Abdan, Khawra, Baihan, Khair); Grazing management; Afforestation in Rudhom; Protection of farmland using gabions	Integrated land management combining soil conservation, reforestation, rotational grazing, and gabion construction to stabilize wadi banks and farmlands.	Protects soils from erosion, combats desertification, stabilizes slopes and wadi banks, safeguards agricultural land, and enhances resilience against floods.
Irrigation & Infrastructure (Rehabilitation & New Construction)	Nisab, Markha Asufla, Bayhan	Rehabilitation of irrigation canals; Construction of new diversion structures, barriers, and channels; Flood protection works **(Output 2.1, 1.3 & 2.3)**	Strengthen existing spate irrigation networks while constructing new diversions and protection systems in key wadis.	Enhances equitable water distribution, prevents flood damage, increases water capture for recharge, and secures agricultural production under variable rainfall.
Integrated Water Resources Management (IWRM)	Markha Asufla, Bayhan	Development of IWRM Plans; Integration of climate and environmental considerations; Monitoring frameworks**(Output 1.1)**	Strategic planning at watershed/district level.	Ensures sustainable, long-term water allocation across sectors under conditions of increasing scarcity and climate variability.

Capacity Building & Awareness	All districts	Training programs; Climate change awareness campaigns; Hygiene campaigns**(Output 1.2)**	Targeted capacity building for communities, farmers, and local institutions.	Strengthens adaptive capacity, empowers communities to manage resources sustainably, and builds awareness of climate risks.

3..1.2 Abyan targeted Districts

Table 32:list of suggested interventions in all targeted districts of Abyan

Category	Districts	Intervention / Project Output	Description	Climate Rationale
Wastewater Management & Sanitation	Lawder, Sarar	Rehabilitation of WWTP (Lawder); Small WWTP & greywater systems (Sarar); Wastewater quality testing; Hygiene & safe reuse awareness	Rehabilitation or construction of wastewater facilities; awareness programs for safe reuse in irrigation.	Prevents contamination of shallow aquifers during drought periods, ecosystem restoration, reforestation of fodders, reduces disease outbreaks (cholera, diarrhea), and enables safe water reused for agriculture during droughts.
Water Quality & Salinity Management	Al-Mahfed, Ahwar	Brackish water treatment unit (Al-Mahfed city); training on the operation of the brackish water desalination, training on water source protection; Water quality testing	Supply, installation, and training for desalination and water quality monitoring systems.	Addresses salinity intrusion (TDS > 5,000 mg/L) that threatens drinking water and irrigation; ensures safe supply in coastal/transitional zones, to address the water scarcity issues.
Water Storage & Supply	All districts	Expansion/rehabilitation of water storage; New rainwater harvesting systems, subsurface dams & cisterns (Sarar); Awareness of sustainable water use	Build/rehabilitate storage tanks and introduce rainwater harvesting and recharge structures.	Increases resilience to droughts, reduces reliance on costly trucking (up to USD 150 per 6,000 L), and safeguards household and livestock needs.
Land Degradation & Desertification Control	All districts	Community-based rangeland management; Soil & water conservation techniques (terracing, check dams, gabions in Sarar); Erosion control in wadis (Ahwar, Al-Mahfed, Lawder); Afforestation and reforestation	Integrated land restoration combining terraces, gabions, grazing management, and reforestation.	Stabilizes soil, reduces erosion, prevents desertification, restores fodder supply, and enhances long-term agricultural resilience.
Irrigation & Infrastructure (Rehabilitation & New Construction)	Ahwar, Al-Mahfed, Lawder	Rehabilitation of spate irrigation canals; Construction of new diversion structures, barriers, and wadi protections (Ahwar–Fuaad & Hanan, Al-Mahfed wadis, Lawder–Shuhat & Thera)	Rehabilitation of deteriorated spate irrigation works and construction of new diversions, recharge, and protection structures.	Improves water distribution efficiency, reduces flood damage, increases aquifer recharge, and sustains farming systems dependent on spate irrigation.

Integrated Water Resources Management (IWRM) & Spatial Planning	Ahawar and Sarar	Development of IWRM Plans; Spatial planning of vulnerable areas; Integration of environmental & climate factors into local planning; Monitoring and evaluation frameworks	Strategic basin/district-level planning to balance water use across agriculture, domestic, and ecosystems.	Ensures sustainable water allocation and climate-adaptive land management in a governorate with rising demand and declining natural resources.
Capacity Building & Climate Change Awareness	All districts	Awareness campaigns on climate change, sustainable water use, wastewater reuse, and community resilience; Training programs for local communities and institutions	Targeted awareness and training to strengthen local knowledge and adaptive capacity.	Build resilience at the community level by promoting behavioral change, supporting local governance, and improving uptake of climate-resilient practices.

3..1.3 Aden

Table 33:list of suggested interventions in all targeted districts of Aden Targeted Districts

Category	Area	Intervention / Project Output	Description	Climate Rationale
Desalination (Pilot Project)	Al Buraiqeh, Ras Amran	Small-scale seawater \brackish RO plant (300–400 m³/day) (Output 1.4)	Pilot desalination system to supply ~3,000–4,000 people with safe drinking water. Serves as a prototype for scaling in future phases.	Addresses immediate drinking water shortages in a city with an 84 MCM annual deficit; reduces reliance on saline groundwater (TDS 5,000–8,000 mg/L).
Capacity Building & Training	Aden	Training on RO operations, O&M of WWTPs, water safety, and IWRM (**Outputs 1.1 & 1.2)**	Technical training for operators, awareness campaigns for communities, and institutional strengthening for water utilities.	Ensures long-term sustainability of prototype desalination, builds resilience for utilities, and empowers households to adopt safe water practices.

3..1.4 Al-Hudaydah Targeted Districts

Table 34: list of suggested interventions in all targeted districts of Al-Hudaydah

Category	Districts	Intervention / Project Output	Description	Climate Rationale
Water Quality & Salinity Management	Al-Khokhah	Brackish water treatment units (RO, 150–200 m³/day) **(Output 1.4)**	Deploy compact reverse osmosis units to treat shallow wells degraded by seawater intrusion, where ~60% of wells are saline.	Responds to severe salinity (TDS > 5,000 mg/L) driven by drought, over-abstraction, and sea-level rise. Provides safe water for ~2,000–3,000 people per unit.
Wastewater & Sanitation	Hays and Al-Khokhah	Small-scale WWTPs (25–50 m³/day) and sewerage pilots **(Output 1.4)**	Construct decentralized WWTP/septic systems to reduce reliance on cesspits, which are the main source of aquifer contamination (E. coli).	Addresses widespread biological contamination; reduces cholera, diarrhea, and typhoid outbreaks; protects shallow aquifers used by >90,000 people.
Capacity Building & Training	Both districts	Training on RO unit and WWTPs operation, maintenance, and safe reuse IWRM (**Outputs 1.1 & 1.2**)	Build technical skills for local operators to manage RO desalination units, routine monitoring, and community awareness on safe water practices.	Ensures sustainability of non-conventional water solutions, strengthens local adaptation capacity, and reduces reliance on unsafe wells.

Agriculture, Ecosystems and Livelihoods

CHAPTER 4

Agriculture, Ecosystems and Livelihoods

6.1 Sector profile and Current status

Agriculture remains the backbone of rural livelihoods in Yemen, employing nearly 53% of the labor force and sustaining about 74% of the population through direct and indirect activities. Despite its central role, the sector faces severe structural and environmental constraints. Only 2–3% of Yemen's total land area is cultivable, and this limited base is under increasing pressure from droughts, erratic rainfall, declining groundwater tables, land degradation, and desertification. Climate change has intensified these risks, resulting in more frequent floods and droughts that reduce yields and heighten vulnerability, particularly for smallholder farmers and rural women, who have limited adaptive capacity.

The protracted conflict has compounded these challenges. Agricultural areas have been damaged, irrigation infrastructure neglected, and farmers face rising fuel costs, shortages of inputs, and restricted access to markets. These constraints have reduced productivity in rainfed systems and deepened reliance on groundwater, accelerating aquifer depletion. At the same time, the spread of qat cultivation has diverted scarce water away from food and cash crops, worsening pressures on water and land resources.

Despite these constraints, agriculture continues to play a critical role in the national economy. In 2023, the sector contributed 12.2% to GDP, equivalent to USD 2.56 billion, with total domestic consumption of agricultural production valued at USD 3.21 billion. Exports amounted to USD 159.5 million, representing more than half of Yemen's non-oil exports, while imports of agricultural goods and services reached USD 903.7 million. Local investment in agricultural infrastructure totaled USD 98 million. The sector thus remains a vital pillar of food security and foreign exchange earnings, even as its relative share in GDP has declined from over 20% before the war. This decline has been strongly influenced not only by conflict-related disruptions but also by climate change impacts, which have reduced rainfed production, increased pressure on groundwater resources, and undermined the stability of farming systems.

Production patterns show that Yemen is largely self-sufficient in vegetables, fruits, and livestock products, while heavily dependent on imports of cereals, edible oils, and sugar. Key high-value exports include honey, coffee, sesame, onions, and fruits such as mango and pomegranate, which enjoy strong regional demand. However, weak value chains, limited processing capacity, and poor infrastructure constrain the sector's competitiveness. Food insecurity remains widespread, with nearly 17 million people at risk and over 40% of households are facing some level of food insecurity.

The targeted governorates of Shabwah and Abyan reflect these national dynamics. Both face similar climate and conflict-related pressures but also offer distinct opportunities through their fertile wadis, diverse cropping systems, and potential in cash crops and livestock. Addressing their vulnerabilities requires tailored interventions that integrate climate-smart technologies, improved irrigation efficiency, livelihood diversification, and ecosystem-

based adaptation, ensuring that agriculture not only supports survival but also contributes to recovery, resilience, and long-term economic sustainability.

6.1 Agricultural and livelihoods profile of Shabwah Governorate

The citizens of Shabwah Governorate have practiced farming as a profession since ancient times, passing it down through generations. The governorate contains vast and fertile agricultural lands where a wide variety of crops are cultivated. It also hosts irrigation facilities, water barriers, and diversion channels that support production. Agriculture in Shabwah is further sustained by its rich network of wadis, which provide vital water catchments for farming, livestock grazing, and groundwater recharge, thereby underpinning food security and the livelihoods of rural communities. The main wadis of Shabwah include:

- Beihan Wadis (targeted district): Supported by tributaries such as Al-Nahr, Khur, and Beihan Wadis.
- Markhah Wadis (targeted district): Includes tributary wadis such as Markhah and Khurah.
- Nisab Wadis (targeted district): Fed by tributaries including Dharaa, Abdan, Hotaib, Al-Hajr, and Binyam (Al-Saeed).
- Mayfa'a Wadis: Contains tributaries such as Aqeeq, Habban, Hada, Majid, Mubarakah, and Salmoon.
- Radhoum Wadis (targeted district): Smaller but significant wadis that support coastal agricultural areas and groundwater recharge.

These wadis form the backbone of Shabwah's agricultural system, with those located in the targeted districts—Beihan, Markhah, Nisab, and Radhoum, being especially critical for sustaining farming communities and guiding future climate-resilient interventions.

4..1 Cultivated Area and production of Crops in Shabwa Governorate

Grains remain a cornerstone of Shabwah's agricultural system, cultivated on 12,413 hectares and producing nearly 5,900 tons in 2023. Wheat occupies the largest area, yet its productivity is extremely low (0.19 t/ha), reflecting reliance on rainfall, low seed quality, and soil fertility decline. Maize performed better, with higher output (over 3,000 tons) but still limited yield levels. Sorghum and millet provide important household food and livestock feed but remain highly vulnerable to rainfall variability. The overall grain productivity of less than 0.5 t/ha underscores the climate-sensitive nature of cereal farming and highlights the urgent need for improved water management, drought-resistant varieties, and soil fertility restoration.

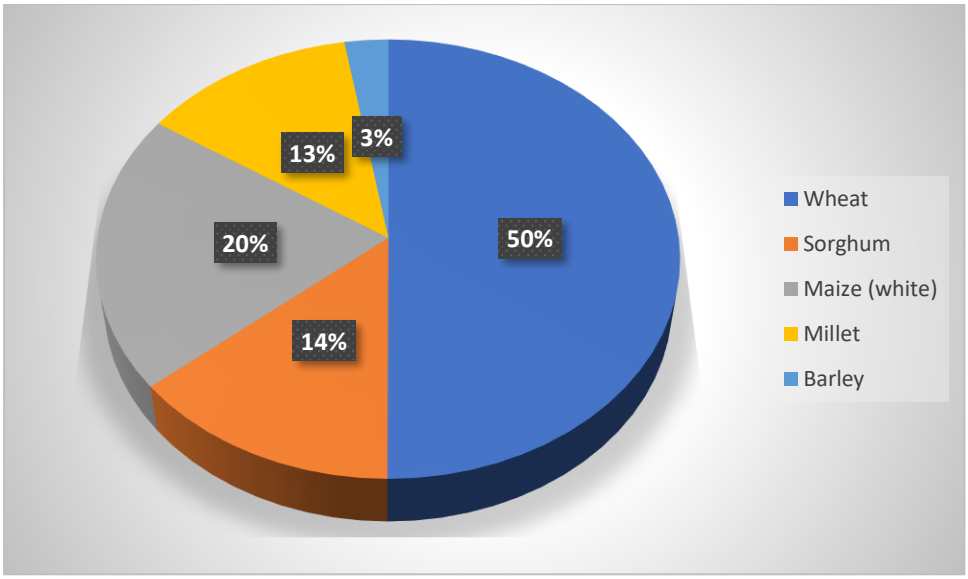


Figure 44:Cultivate area of grains in Shabwah

Table 35:Baseline data of grains in Shabwah — Production, and Productivity (2023)

Crop	Production (t)	Productivity (t/ha)
Wheat	1,187	**0.19**
Sorghum	607	**0.35**
Maize (white)	3,069	**1.21**
Millet	823	**0.51**
Barley	201	**0.61**
Total Grains	**5,887**	**0.47**

Vegetables cover around 1,915 hectares and produced 16,767 tons in 2023, contributing significantly to household nutrition and local markets. Red onion and tomato dominate, with onion achieving high yields (over 24 t/ha) despite challenges in storage and post-harvest handling. Secondary crops such as potato, carrot, cucumber, and leafy greens diversify the diet but are cultivated on small plots with uneven yields. The vegetable sector demonstrates strong production potential, but expansion is constrained by high water demand, pest outbreaks, and limited market

infrastructure. Strengthening irrigation efficiency, cold storage, and transport logistics could significantly enhance productivity and reduce post-harvest losses.

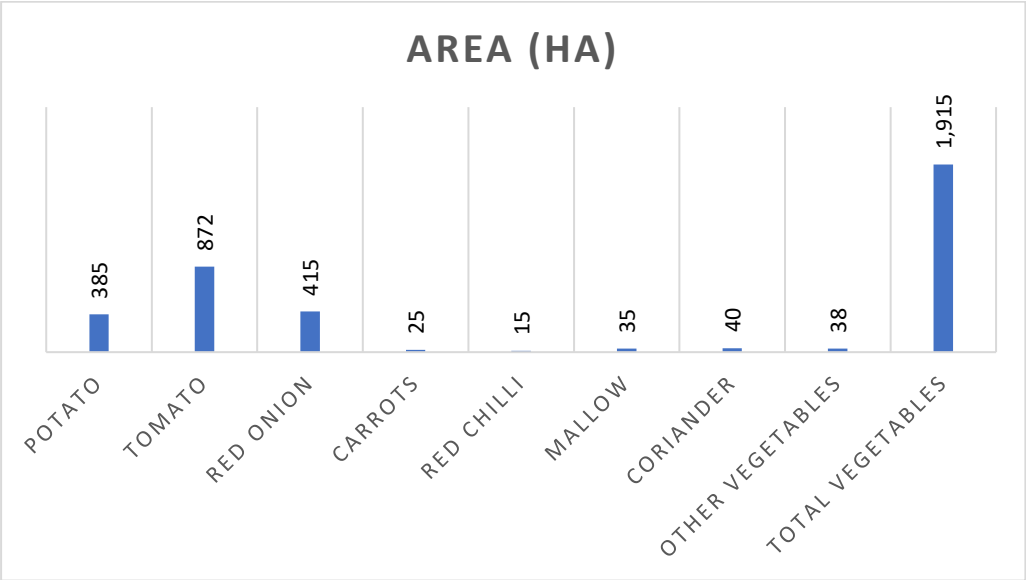


Figure 45:Cultivated area of vegetables

Table 36:Baseline data of vegetables in Shabwah — Area, Production, and Productivity (2023)

Crop	Production (t)	Productivity (t/ha)
Potato	1,053	**2.74**
Tomato	4,053	**4.65**
Red onion	10,267	**24.74**
Carrots	103	**4.12**
Red chilli	201	**13.40**
Mallow	195	**5.57**
Coriander	215	**5.38**

Other vegetables	150	**3.95**
Total Vegetables	**16,767**	**8.76**

Fruit cultivation spans 2,047 hectares, generating over 21,000 tons in 2023. Key crops include watermelon, citrus, mango, lemon, and dates, with high-value fruits such as dates and citrus achieving productivity close to 10 t/ha. Despite this potential, production declined from 2022 levels due to water shortages, pest infestations, and climate variability. The sector holds strong opportunities for value addition and regional exports, but requires investments in irrigation, pest management, and value chain development to stabilize output. Climate-smart orchard management practices, coupled with improved cold storage and processing facilities, could unlock significant income-generating opportunities for farming households

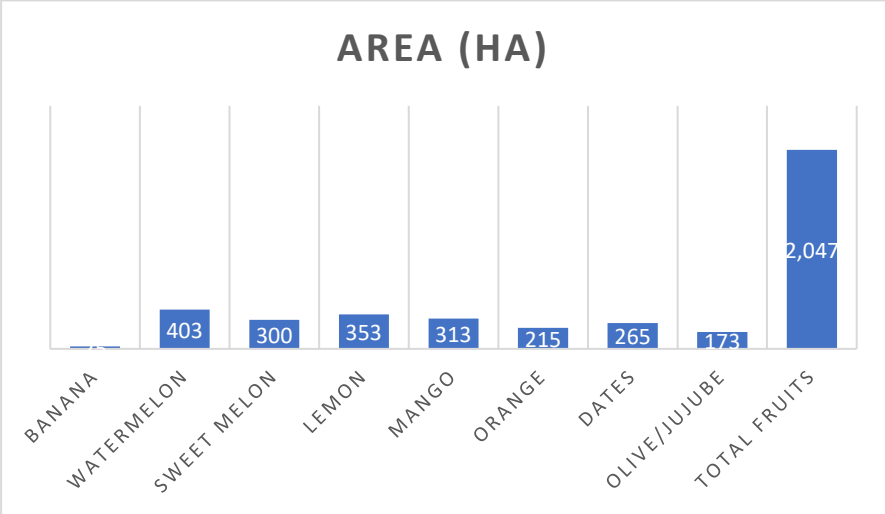


Figure 46:Fruits Cultivated Area in Shabwah

Table 3:

Table 37:Baseline data of fruits in Shabwah — Area, Production, and Productivity (2023)

Crop	Production (t)	Productivity (t/ha)
Banana	117	**4.68**
Watermelon	8,145	**20.21**

Sweet melon	968	**3.23**
Lemon	2,094	**5.93**
Mango	1,238	**3.96**
Orange	2,092	**9.73**
Dates	2,589	**9.78**
Olive/Jujube	2,063	**11.92**
Total Fruits	**21,163**	**10.34**

Cash crops accounted for 1,920 hectares and yielded over 4,000 tons in 2023. Sesame dominates, covering more than half the cash crop area and achieving high productivity (3.78 t/ha), making it the governorate's most promising commercial crop. Tobacco is also present but with much lower productivity, while cotton, peanuts, and coffee were not reported in 2023. The dominance of sesame reflects its strong adaptation to Shabwah's agro-ecological conditions, yet the narrow diversity of cash crops leaves farming systems exposed to climate and market risks. Scaling up sesame value chains, including oil extraction and marketing, could provide an entry point for rural income diversification and resilience-building.

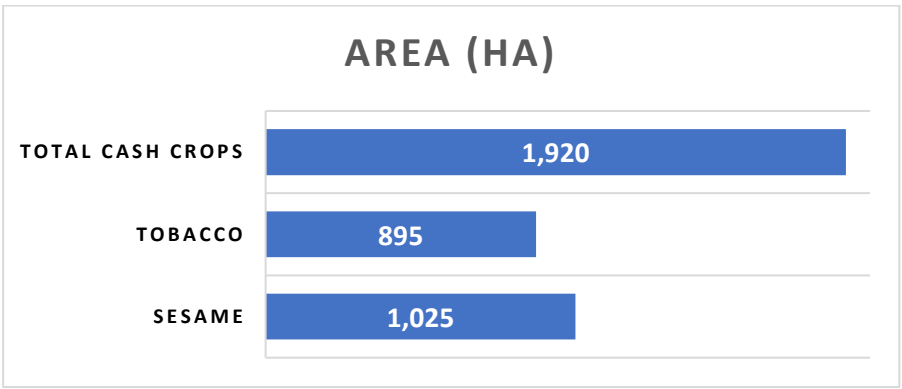


Figure 47:Cash Crops Cultivated Area in Abyan

Table 38:Baseline data of cash crops in Shabwah — Area, Production, and Productivity (2023)

Crop	Area (ha)	Production (t)	Productivity (t/ha)
Sesame	1,025	3,875	**3.78**
Tobacco	895	193	**0.22**
Total Cash Crops	**1,920**	**4,068**	**2.12**

Fodder crops dominate agricultural land use in Shabwah, covering 16,716 hectares and producing an estimated 162,021 tons in 2023. Grass and alfalfa are widely grown alongside corn feed, achieving productivity levels of 8–10 t/ha. This reflects the governorate's strong dependence on livestock production, with goats, sheep, camels, and cattle forming a critical component of rural livelihoods. However, heavy reliance on fodder also amplifies pressure on limited water resources, particularly groundwater abstraction. Investments in forage management, water harvesting, and integrated crop-livestock systems will be essential to sustain productivity while reducing pressure on fragile ecosystems.

Table 39:Baseline data of fodder in Shabwah — Area, Production, and Productivity (2023)

Crop	Area (ha)	Production (t)	Productivity (t/ha)
Corn feed	5,520	45,000	**8.15**
Alfalfa	3,194	32,665	**10.23**
Grass	8,002	84,356	**10.54**
Total Fodders	**16,716**	**162,021**	**9.69**

Year-on-year production trends reveal a mixed performance shaped by climate variability. Grain production increased modestly, but yields remain extremely low and climate-sensitive. Vegetables and fruits recorded declines, with citrus and "other vegetables" showing the steepest drops, reflecting water shortages and pest pressures. Cash crops, particularly sesame, performed strongly with output more than doubling, while fodder production surged to meet livestock demand. These shifts underscore the dual challenge facing farmers: declining productivity in food crops under climate stress and the expansion of crops better suited to local agro-climatic conditions, such as sesame

and fodder. For a climate-resilient future, Shabwah's agriculture will require diversification, investment in irrigation and soil fertility, and stronger integration of value chains to stabilize rural livelihoods.

4..2 Livestock Wealth and Production Trends for 2022–2023

Livestock husbandry is a cornerstone of rural livelihoods in Shabwah, providing meat, milk, hides, wool, and income diversification. Herds are closely tied to fodder availability and rangeland productivity, linking them directly to the broader agricultural system. Climate change, recurrent droughts, and fodder shortages increasingly shape herd composition and productivity, influencing household strategies and market outcomes.

Livestock numbers in 2023 reflect both stability and significant shifts in herd structure. Camels remained unchanged at around 14,000 head, highlighting their niche role in arid zones. Cattle increased slightly, while small ruminants showed divergent trends: mutton herds grew by 24%, but lambs declined by over 34%, suggesting pressure on reproduction cycles and grazing resources. These fluctuations indicate households are adjusting herd composition in response to fodder availability, market demand, and climate-related stress on pastures.

Table 40:Estimated Number of Livestock Wealth (Thousand Head, 2022–2023)

Item	2023	2022	Trend
Camel	14	14	Stable
Beef cattle	30	28	+2,000 head
Lamb (sheep young)	635	965	−330,000 head
Mutton (adult sheep/goats)	743	600	+143,000 head

Livestock production in 2023 generated an estimated 12,190 tons of meat, with lamb and mutton accounting for nearly 90% of total output. Camel and beef contributed smaller shares, while poultry provided an additional income stream valued at nearly 29 million YR. Beyond meat, secondary products play a vital role in rural economies: egg production exceeded 81 million units, honey reached 199 tons and hides and wool supported cottage industries and trade. These outputs highlight the sector's diversity and its importance in sustaining household resilience. However, productivity remains highly dependent on fodder supply, rangeland health, and climate variability, leaving rural incomes exposed to shocks.

Table 41:Livestock Production and Value (2023)

Item	Quantity (t / units)	Value (000 YR)
Meat (total)	12,190 t	162,890
– Lamb	6,781 t	88,153
– Mutton	4,347 t	56,511
– Camel	789 t	8,671
– Beef	273 t	9,555
Eggs	81 million units	1,215
Honey	199 t	24,776
Leather (hides)	950 units	2,850

Livestock remains an essential pillar of Shabwah's rural economy, providing food security, income, and cultural value. While total herd numbers have remained broadly stable, significant shifts in compositions such as the decline in lambs and the increase in mutton—reflect the impacts of climate variability, grazing pressures, and household adaptation strategies. Production is diversified across meat, milk, eggs, honey, hides, and wool, but remains highly sensitive to fodder availability and rangeland conditions. Strengthening the resilience of this sector through sustainable fodder production, rangeland rehabilitation, veterinary services, and value-chain development will be critical to safeguarding rural livelihoods and ensuring the long-term sustainability of Shabwah's agro-pastoral systems.

4..3 Fish Production and Marine Life in Shabwah Governorate

The fisheries sector is one of the most vital pillars of Shabwah's economy, sustaining thousands of coastal households through food security, income generation, and employment. Marine resources provide both high-value export commodities and essential local nutrition, with artisanal and traditional fishing forming the backbone of the sector. However, this system remains highly vulnerable to overfishing, weak management capacity, and climate-induced pressures on marine ecosystems, all of which threaten long-term sustainability.

Aquatic and deep-water fisheries contributed modestly in 2023, with a combined 42 tons valued at 102 million YR, representing a small share of the overall catch but illustrating the diversity of marine resources available to the artisanal fleet. Tuna and related pelagic species dominate the governorate's fishery, with Tuna Thunnid alone contributing 256 tons valued at over 767 million YR. Other pelagic and reef-associated species, including Indian mackerel, fusiliers, and sharks, add significant supplementary value. The category "other kinds of fishes" (1,147 tons) underscores the multi-species nature of artisanal fishing and its importance for local food supply, while cuttlefish (30 tons) adds further diversity. Overall, marine production in 2023 reached 15,657 tons valued at nearly 36.7 billion YR, confirming fisheries as a backbone of Shabwah's coastal economy.

Fishing infrastructure and organization are under pressure. The number of registered boats declined from 1,356 in 2022 to 1,059 in 2023, indicating a reduction in active fleet capacity. Yet the number of fishermen increased to 2,112, highlighting the continued reliance of households on marine livelihoods. Cooperative societies also grew slightly, from 12 to 13, reflecting efforts to strengthen community-based management and shared market access.

In the context of climate change impacts on agriculture, fisheries represent a crucial pathway for livelihood diversification. With recurrent droughts, erratic rainfall, and groundwater depletion, reducing agricultural yields, the marine sector offers a critical alternative source of income, employment, and nutrition. Supporting fisheries through investments in cold storage, fish processing, value chain development, and sustainable fishing practices will be essential not only to reduce post-harvest losses but also to enhance resilience, diversify rural livelihoods, and secure long-term economic sustainability for coastal communities in Shabwah.

4..4 Sector Profile of the Targeted Districts

The targeted districts of Beihan, Markhah, Nisab, and Radhoum reflect the diversity of Shabwah's agro-ecological zones, spanning fertile inland valleys, semi-arid uplands, and vulnerable coastal areas. These districts are characterized by mixed farming systems that combine crop cultivation, livestock rearing, and in Radhoum, coastal fisheries. They are sustained by key wadis that recharge groundwater and support agriculture, yet all face mounting pressures from climate variability, recurrent droughts, flash floods, land degradation, and salinity intrusion. Together, they illustrate the challenges and opportunities for building climate-resilient livelihoods in Shabwah, where targeted interventions in water management, agriculture, livestock, and fisheries can significantly strengthen food security and household resilience.

4..4.1 Nisab Districts

Nisab District is one of the most important agricultural areas in Shabwah Governorate, supported by wadis such as Abdan, Dhara'a, Al-Hanak, Al-Awsha, and Al-Hajr, which sustain farming activities and recharge groundwater resources. The local economy relies heavily on trade, crop cultivation, beekeeping, and livestock rearing, making these the primary livelihood activities for rural households. The district contributes nearly 30% of Shabwah's total agricultural production, underscoring its central role in both food security and market supply.

Agricultural production in Nisab is highly diverse. Key cereal crops include wheat, millet, sorghum, and maize, while vegetables such as potatoes, tomatoes, onions, garlic, carrots, cucumber, zucchini, eggplant, and peppers are widely cultivated. The district also produces legumes (lentils, beans, fenugreek), aromatic and medicinal plants (fennel, coriander, parsley, mint, henna), and a wide range of fruits including dates, watermelon, sweet melon,

oranges, and lemons. Fodder crops such as alfalfa, maize, Rhodes grass, and grapevine leaves support livestock husbandry, which remains integral to household resilience.

Beekeeping is another cornerstone of rural livelihoods in Nisab. The district is renowned for its production of high-quality honey, particularly from Sidr trees, which are valued both economically and culturally. Sidr honey is one of Yemen's most sought-after products, providing rural households with critical supplementary income while also sustaining a traditional practice passed down through generations.

This rich agricultural and natural resource base highlights Nisab's role as a production hub within Shabwah. However, its farming and beekeeping systems remain vulnerable to climate change impacts, including rainfall variability, prolonged droughts, and water scarcity. These stresses threaten long-term productivity, food security, and the resilience of rural livelihoods, making climate-smart agriculture, improved water management, and sustainable apiculturevital priorities for the district's future.



Figure48 :Agricultural Lands in Nisab

4..4.2 Bayhan

Bayhan District is one of the governorate's most fertile valleys and a major agricultural hub. Covering an estimated 4,500 hectares, the district has long relied on agriculture as the foundation of rural livelihoods, with farming traditions passed down through generations. Two major wadis — Wadi Al-Nahr and Wadi Al-Khair — sustain agricultural activity by providing water for irrigation, soil fertility, and groundwater recharge, making them the lifeline of farming and livestock systems in the valley.

Agricultural production in Bayhan is dominated by grains and fodder crops, which together account for more than 66% of the cultivated area (34.1% grains, 32.1% fodders). Cereals include wheat, millet, sorghum, barley, and maize, while fodders provide essential livestock feed. Vegetables (19.5%) such as potatoes, tomatoes, cucumbers, zucchini, legumes, and aromatic crops like fennel and fenugreek are widely grown, followed by cash crops (9.3%), primarily sesame and palm dates. Sesame (*"al-juljul"*) is the hallmark crop of Bayhan, cultivated for high-quality oil extraction, with traditional sesame oil presses providing both employment and a cultural heritage industry. Palm dates are also a key crop in Shabwah, valued for their nutritional and commercial importance, with strong potential for value chain development in processing and export



Figure49 :Agriculture lands and in Bayhan

Beyond crops, honey production—particularly Sidr honey from Bayhan's valleys—is a renowned livelihood activity, recognized for its superior quality and high market value both locally and internationally. Beekeeping complements agriculture and provides a vital source of cash income for rural households, while also linking to ecosystem health and biodiversity.

Livestock husbandry remains equally important. Small ruminants dominate, with sheep (46%) and goats (32%) forming the majority of herds due to their adaptability to limited rangeland and small farm sizes. Poultry (14%) and beekeeping (≈5%) also play important roles in food security and diversification of income. Sheep rearing in particular benefits households through shorter production cycles, strong consumer demand for meat and milk, and the ability to secure multiple generations per year.

Overall, Bayhan's rural economy reflects a balanced mix of cereals, fodders, vegetables, and high-value cash products such as sesame, palm dates, and Sidr honey, reinforced by small ruminant livestock and apiculture. However, these systems are increasingly vulnerable to climate variability, recurrent droughts, and water scarcity, which threaten crop yields, pasture productivity, and bee forage. Strengthening water management in Wadi Al-Nahr and Wadi Al-Khair, modernizing value chains for sesame, dates, and honey, and supporting fodder and livestock systems will be critical to sustaining livelihoods and building long-term resilience in Bayhan.

4..4.3 Markha Al Sufla

Markhah District, located in western Shabwah, is an agriculturally active area supported by the fertile valleys of Wadi Markhah and Wadi Khoura, which serve as the district's main agricultural lifelines. These wadis provide irrigation water, recharge groundwater, and sustain crop cultivation, but they are increasingly affected by seasonal flash floods that damage fields and erode soils, disrupting agricultural productivity and threatening household food security.

Agriculture in Markhah is characterized by a mix of staple and cash crops. The most important crops include potatoes, tomatoes, onions, and wheat, alongside sorghum (red maize), legumes, sesame, and fodder crops that support livestock. This diversity highlights the district's potential for both subsistence and market-oriented farming. However, the expansion of agriculture is constrained by land degradation, soil erosion, and declining fertility, which undermine long-term productivity and exacerbate vulnerability to climate variability.

Livelihoods in Markhah depend heavily on farming and livestock, with smallholders cultivating mixed plots and rearing goats, sheep, and cattle. Yet with agriculture increasingly exposed to flood risks, drought cycles, and land degradation, rural households face growing livelihood insecurity. Diversifying income sources beyond crop farming—such as through beekeeping, fisheries, small trade, and value-added processing of crops like sesame and vegetables—is critical to reducing risks and enhancing resilience.

Overall, Markhah's economy is anchored in its wadis and fertile valleys, but sustaining livelihoods will require integrated watershed management, soil conservation measures, improved irrigation systems, and livelihood diversification strategies. Strengthening these areas will help secure both agricultural output and household resilience in the face of intensifying climate change impacts.



Figure50 :Agricultural lands from Markha District

4..4.4 Roduhom

Rodhoum District is Shabwah's primary coastal district and one of the most strategically important zones for agriculture, livestock, and fisheries. Its fertile coastal plains and valleys support diverse crop cultivation, while its shoreline provides abundant marine resources, making Rodhoum a hub of both farming and fishing livelihoods.

Agriculture in Rodhoum is centered on a wide range of cereals such as maize, wheat, millet, and tahaf (a local grain), alongside cash crops like sesame. The district also produces significant quantities of vegetables including tomatoes, zucchini, onions, arugula, and radish, as well as fruits such as citrus, guava, mango, dates, watermelon, and sweet melon. This mix of cereals, vegetables, and fruits makes Rodhoum one of the most agriculturally diverse districts in Shabwah, with both subsistence and market-oriented potential. However, agricultural productivity is increasingly constrained by salinity intrusion, coastal flooding, and climate variability, which threaten long-term sustainability.

Livestock plays a critical role in rural livelihoods. Rodhoum exports more than 100,000 head of sheep annually, both to domestic and external markets, making it one of Shabwah's leading contributors to the livestock trade. Sheep and goats dominate herds due to their adaptability to semi-arid and coastal grazing systems, while cattle and camels remain secondary. This livestock trade is a vital source of household income but is highly sensitive to fodder shortages, overgrazing, and rangeland degradation linked to droughts and climate stress.

Fisheries are Rodhoum's defining sector. As Shabwah's first-ranked fishing district, Rodhoum contributes a substantial share of the governorate's marine production. In 2023, fisheries contributed 42 tons valued at YR 102 million, though this figure underrepresents the district's actual role in artisanal and commercial fishing. Rodhoum's coastal waters provide tuna, mackerel, cuttlefish, snapper, and other pelagic species, supplying both local markets and national demand. Fishing livelihoods rely on small-scale boats and traditional gear, but climate change—through rising sea surface temperatures, stronger storms, and coastal ecosystem degradation—is placing growing pressure on stocks and infrastructure.



Figure 51:Agricultural land and coast for Radhoum District

Overall, Rodhoum District embodies the intersection of agriculture, livestock, and fisheries in Shabwah's economy. Its strength lies in its diversified production base: cereals and vegetables for food security, sesame and dates for cash income, sheep exports for trade, and fisheries for national and local markets. Yet all three sectors face climate-induced risks, from salinity intrusion and soil erosion in agriculture, to fodder scarcity for livestock, and warming seas for fisheries. To secure long-term resilience, Rodhoum requires integrated interventions in coastal resource management, water and soil conservation, livestock feed systems, and fisheries value chain development—all of which can stabilize rural incomes and strengthen its role as Shabwah's coastal economic hub**.**

6.1 Agricultural and livelihoods profile of Abyan Governorate

The people of Abyan Governorate have practiced farming for centuries, passing down traditional agricultural knowledge through generations. The governorate contains wide stretches of fertile land, particularly in its deltaic plains, where cereals, vegetables, fruits, and cash crops are cultivated. Irrigation facilities, spate diversion structures, and water barriers play a central role in sustaining production, especially in the delta areas, while groundwater and rainfed systems complement farming in upland zones. Agriculture in Abyan is further supported by its network of wadis, which recharge aquifers, sustain grazing lands, and ensure the food security and livelihoods of rural households.

The main wadis of Abyan include:

- Wadi Bana (Delta Abyan): The largest and most important wadi system in the governorate, forming the fertile Abyan Delta. It supports extensive cultivation of cereals (maize and millet), vegetables, and fruit orchards, and underpins the governorate's food basket role at the national level.
- Wadi Hassan: A major tributary system that provides irrigation and supports mixed farming, particularly for fruit and cash crops, while also contributing to groundwater recharge.
- Wadi Ahwar: Extending to the coastal zone, this wadi sustains agriculture in Ahwar district, supporting dates, millet, and vegetables, and provides vital grazing areas.
- Wadi Dos and other smaller wadis: These contribute to localized farming systems, livestock watering, and rural household resilience, though they are increasingly constrained by climate variability.

Together, these wadis form the backbone of Abyan's agricultural economy. Delta Abyan (Wadi Bana) is recognized as one of Yemen's most fertile agricultural zones, though it is also highly exposed to climate hazards such as floods, droughts, and seawater intrusion. The productivity and resilience of these systems will be central to sustaining rural livelihoods, and those located in targeted districts—such as Delta Abyan, Ahwar, and coastal plains—are especially critical for guiding future climate-resilient interventions.

4..1 Cultivated Area and production of Crops in Abyan Governorate

Agriculture in Abyan covers a diverse range of crops, with an estimated 31,000 hectares cultivated in 2023. The crop mix highlights the importance of cereals (particularly maize and millet) for food security, alongside significant cash crops (sesame and cotton), fruits (bananas and watermelon), and a variety of vegetables. However, the sector is increasingly shaped by climate stress, with heavy reliance on a few crops leaving the system vulnerable to rainfall variability, recurrent droughts, and floods that affect the Abyan Delta.

Grains occupy more than half of Abyan's cultivated land (15,500 ha) but yields are extremely poor due to droughts, erratic rainfall, and degraded soils. Wheat maintains modest performance, but sorghum collapsed almost entirely in 2023, showing its vulnerability to rainfall failure. Maize and millet, traditionally drought-tolerant—showed slightly better resilience but still produced negligible volumes compared to their large areas. This highlights the fragility of staple food systems under climate change.

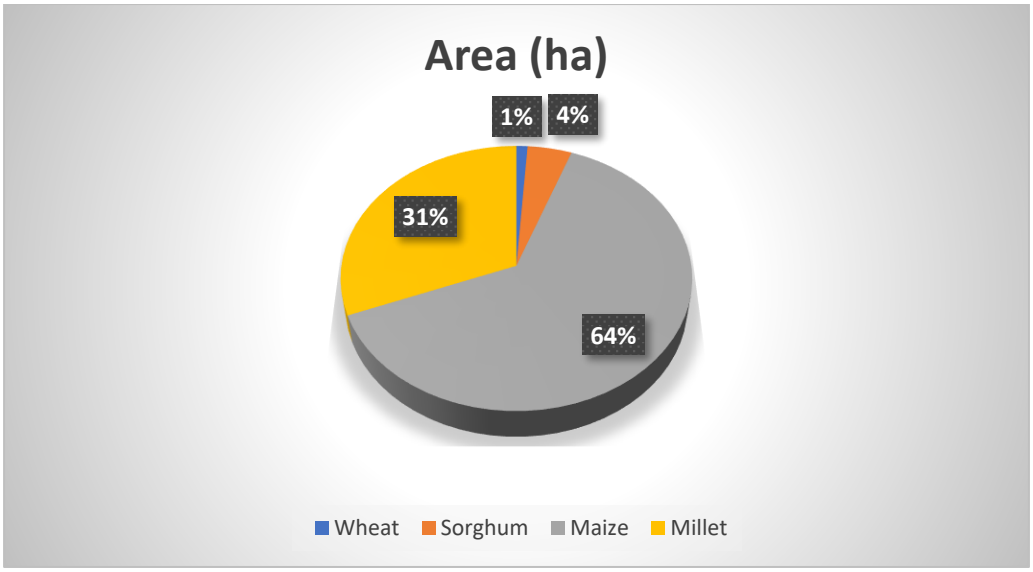


Figure 52:Grain Cultivated Area in Abyan

Table 42:Baseline data of grains in Abyan — Area, Production, and Productivity (2023)

Crop	Production (t)	Productivity (t/ha)
Wheat	175	1.00
Sorghum	1.66	0.002 (collapsed)
Maize	16.76	0.002
Millet	12.50	0.003
Total Grains	**206**	**0.01 (average)**

Vegetables are cultivated on 2,200 ha and produced 1,116 tons in 2023, a sharp decline from 2022. Tomatoes, onions, and chillies remain the mainstay, with red chilli recording high productivity. However, most vegetables such as okra and green onion collapsed under water shortages, pest infestations, and rising heat stress. The disappearance of legumes further reduces dietary diversity and soil fertility. Without irrigation efficiency, pest control, and cold storage, Abyan's vegetable sector will remain highly climate sensitive.

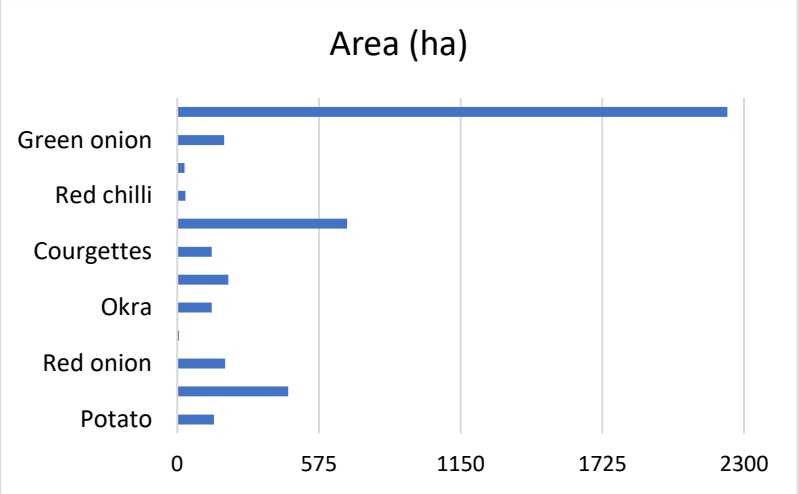


Figure 53:Cultivated Area of Vegetables in Abyan

Table 43:Baseline data of Vegetables in Abyan — Area, Production, and Productivity (2023)

Crop	Area (ha)	Production (t)	Productivity (t/ha)
Potato	149	152	1.02
Tomato	450	5.41	0.01
Red onion	194	2.54	0.01
Carrot	8	60	7.50
Okra	140	6	0.04
Eggplant	208	164	0.79
Courgettes	140	1.08	0.01
Green chilli	690	2,645	3.83
Red chilli	34	720	21.18

Legumes	30	–	–
Green onion	190	2.26	0.01
Total Vegetables	**2,233**	**1,116**	**0.50 (average)**

Fruit farming covers 3,700 ha, centered in Delta Abyan and coastal plains. Production fell to 952 tons in 2023, largely due to the loss of dates and reduced yields across bananas, melons, and oranges. Lemons remain a strong performer, with nearly 6 t/ha, showing potential for citrus value chains. Overall, fruit orchards are highly sensitive to drought, floods, and salinity intrusion in delta areas, requiring climate-smart orchard management and irrigation modernization.

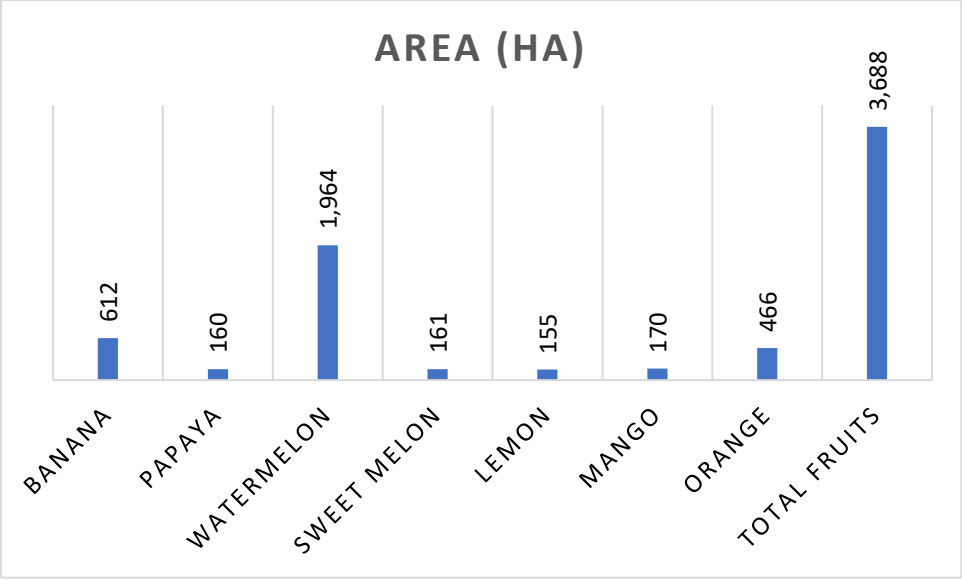


Figure 54:Fruits Cultivated Area of Abyan

Table 44:Baseline data of Fruits in Abyan — Area, Production, and Productivity (2023)

Crop	Production (t)	Productivity (t/ha)
Banana	10.7	0.02
Papaya	2.3	0.01
Watermelon	18.6	0.01
Sweet melon	1.9	0.01
Lemon	912	5.88
Mango	15.9	0.09
Orange	5.2	0.01
Dates	–	– (disappeared)
Total Fruits	952	0.26 (average)

Cash crops occupy nearly one-third of Abyan's cultivated area (9,600 ha), led by sesame, cotton, and peanuts. Despite this, production is extremely low, with the exception of coffee, which produced 494 tons at 0.6 t/ha and shows resilience in upland systems. The collapse of sesame and cotton yields highlights the vulnerability of export crops to irrigation shortages and extreme climate events. Revitalizing sesame and coffee value chains could provide critical income diversification and resilience if coupled with market and irrigation support.

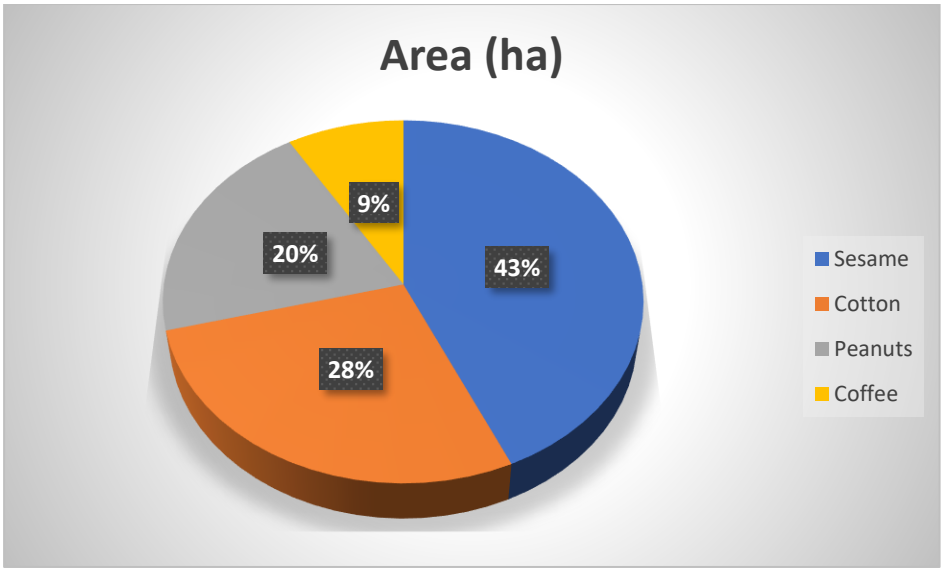


Figure 55:Cas crops cultivated area of Abyan

Table 45:Baseline data of cash crops in Abyan — Area, Production, and Productivity (2023)

Crop	Area (ha)	Production (t)	Productivity (t/ha)
Sesame	4,152	4.2	0.001
Cotton	2,664	2.3	0.001
Peanuts	1,960	1.6	0.001
Coffee	828	494	0.60
Total Cash Crops	9,604	502	0.05 (average)

The cultivated crop systems of Abyan reveal both their economic significance and their acute vulnerability to climate change. Despite a total cultivated area of over 31,000 ha, overall production has sharply declined due to erratic rainfall, recurrent droughts, floods, and salinity intrusion in the Abyan Delta. Grains, which dominate land use, deliver very low yields, while vegetables and fruits—though critical for household nutrition and markets—have suffered from water stress and pest outbreaks. Cash crops such as sesame and cotton, once central to rural incomes, are collapsing under irrigation shortages, leaving coffee as the only relatively resilient performer. The disappearance of legumes and fodder crops has further weakened soil fertility and livestock feed systems, undermining integrated farming practices. These trends underscore the urgent need for climate-resilient agriculture

in Abyan, including investment in modern irrigation, drought-tolerant varieties, and value chain development, to stabilize production, safeguard food security, and build adaptive capacity against intensifying climate risks.

4..2 Livestock Wealth and Production Trends for 2022–2023

Livestock husbandry is an integral part of Abyan's rural economy, providing food, income, and cultural value. In 2023, the governorate's herds were dominated by small ruminants, supplemented by cattle and camels. However, herd productivity and composition remain closely tied to fodder availability, rangeland conditions, and climate variability. Droughts, reduced fodder production, and rangeland degradation are reshaping herd structures and exposing pastoral livelihoods to increasing risk.

Abyan's livestock wealth is dominated by sheep and goats (≈1.4 million head), which form the backbone of household food security and trade. Cattle (30,000 head) provide beef and dairy, while camels (14,000 head) play a niche role in arid grazing systems. However, the absence of fodder crop production in 2023 signals growing pressure on rangelands, increasing risks of overgrazing and land degradation. Climate stress is already influencing herd composition, with households prioritizing small ruminants for quicker turnover and adaptability, though these remain highly vulnerable to recurrent droughts.

Table 46:Estimated Number of Livestock in Abyan (2023)

Species	Number (thousand head)	Trend (2022–2023)
Camels	14	Stable
Cattle	30	Stable
Lambs	635	Large share of herd, vulnerable to fodder shortages
Mutton (adult sheep/goats)	743	Large share of herd, critical for meat & trade

Livestock products in Abyan are diverse and complement crop-based systems. Poultry production (6,000 t) provides an accessible and resilient source of protein, less dependent on rangeland resources. Honey (316 t) is a high-value livelihood stream, reflecting the role of beekeeping in rural diversification. However, declining vegetation cover from climate stress threatens apiculture, while poultry production is constrained by feed costs and veterinary gaps.

Table 47:Livestock Production in Abyan (2023)

Product	Quantity	Notes
Poultry meat	6,000 t	Primary source of protein; lower water footprint than cattle
Honey	316 t	High-value product linked to rangeland and tree cover

Livestock in Abyan continues to sustain rural livelihoods, but the system is becoming increasingly vulnerable under climate change. The decline in fodder crops, coupled with rangeland degradation, undermines the long-term viability of herds. Small ruminants remain the most important livelihood asset but are highly exposed to droughts and disease outbreaks. Poultry and honey provide climate-resilient alternatives, yet require improved inputs, veterinary services, and market access. Building resilience in Abyan's livestock systems will depend on sustainable rangeland management, fodder production, ecosystem restoration, and value-chain development to protect both household food security and rural incomes.

4..3 Fish Production and Marine Life in Abyan Governorate

Fisheries represent one of Abyan's most important economic sectors, sustaining thousands of coastal households through food, employment, and trade. Marine resources provide high-value export commodities such as tuna and cuttlefish while also supporting local consumption and nutrition. The sector, however, is highly vulnerable to overfishing, rising sea surface temperatures, shifting fish migration patterns, and storm surges linked to climate change.

Total fish production in 2023 reached 17,063 tons valued at YR 54.4 billion, confirming fisheries as a cornerstone of Abyan's economy. Surface water fish dominated output (13,696 tons), reflecting their importance to traditional fishing practices, while aquatic catch contributed a smaller share (3,367 tons). The concentration of catches in nearshore ecosystems underscores both the sector's accessibility and its vulnerability to coastal ecosystem degradation and extreme climate events.

Table 48:Fish Production in Abyan by Category (2023)

Category	Quantity (t)	Value (000 YR)
Aquatic catch	3,367	16,062,835
Surface water fish	13,696	38,348,475

Total	**17,063**	**54,411,310**

Cuttlefish emerged as a high-value export species, contributing 2,593 tons worth YR 12.97 billion. Other miscellaneous fish added 774 tons, while surface water fish dominated in both volume and value. This reliance on a limited set of species increases exposure to overfishing pressures and climate-induced shifts in marine biodiversity, highlighting the need for stock management and diversification.

Tuna remains the backbone of Abyan's fisheries, contributing 7,194 tons valued at YR 20.1 billion. Indian mackerel (2,876 tons) and cuttlefish (2,593 tons) also rank as major contributors, together with tuna accounting for the bulk of fishery revenues. Other species such as snapper, fusiliers, and sharks enrich the diversity of the catch, supporting both domestic consumption and trade. However, this concentration in a few high-value species increases Abyan's vulnerability to stock depletion, warming seas, and changing migratory patterns.

Table 49:Fish Production in Abyan by Type (2023)

Type	Quantity (t)	Value (000 YR)
Tuna Thunnid	7,194	20,143,200
Longtail tuna	111	310,800
Little tuna	177	494,662
King fish	108	303,369
Cobia	146	408,240
Spotted shark	274	768,040
Snapper	739	2,069,200
Gold band fusilier	1,059	2,966,048
Indian mackerel	2,876	8,052,716

Other kinds (fishes)	1,012	2,832,200
Cuttlefish	2,593	12,966,115
Other crustaceans & cephalopods	774	3,096,720
Total	**17,063**	**54,411,310**

Abyan's fisheries sector is supported by 4,651 boats and 8,419 fishermen, dominated by small-scale traditional vessels. The presence of 12 cooperative societies provides a foundation for collective organization, though capacity remains limited. The high boat-to-fisherman ratio suggests shared, small-scale operations, which provide widespread access but limit efficiency and safety. With climate change bringing stronger storms and declining fish stocks, strengthening cooperatives, upgrading fleets, and investing in cold storage, processing, and safety infrastructure are vital for sustaining coastal livelihoods.

Table 50:Fish Cooperative Societies and Fishermen's Boats in Abyan (2023)

Item	Number
Boats	4,651
Fishermen	8,419
Cooperative societies	12

Fisheries in Abyan are both a vital source of food and income and a critical adaptation pathway for rural households facing collapsing agricultural productivity due to droughts, floods, and salinity intrusion in Delta Abyan. With revenues exceeding YR 54 billion in 2023, the sector already provides a strong economic base, yet its overreliance on tuna, mackerel, and cuttlefish makes it fragile. Targeted investments in sustainable fisheries management, cooperative strengthening, and value-chain development will be essential to safeguard marine ecosystems, reduce post-harvest losses, and create diversified income streams. By doing so, fisheries can serve as a buffer and diversification strategy for climate-affected communities, helping stabilize livelihoods and strengthen long-term resilience.

4..4 Sector Profile of the Targeted Districts of Abyan

Abyan Governorate is one of Yemen's most agriculturally productive regions, sustained by the fertile Delta Bana and an extensive network of wadis that recharge groundwater and support year-round farming. Agriculture is the backbone of rural livelihoods, with cereals such as maize, millet, and sorghum forming the food security base, complemented by sesame, cotton, peanuts, and coffee as important cash crops. Fruit orchards of bananas, citrus, mango, and watermelons, alongside diverse vegetables like tomatoes, onions, and chillies, contribute to diets and local markets, while livestock rearing and the production of Sidr honey remain vital income sources. Abyan is also a coastal governorate with a thriving fisheries sector that sustains thousands of households and generates high-value exports. Yet, this wealth of natural resources is increasingly threatened by climate change impacts—including recurrent floods, droughts, salinity intrusion, and land degradation—placing pressure on traditional livelihoods and underscoring the urgent need for climate-resilient agriculture, fisheries management, and diversified livelihood strategies.

4..4.1 Lowder

Lowder stands as one of the most prominent agricultural and pastoral centers in southern Yemen, contributing nearly 30% of Abyan's total livestock wealth. The district is particularly renowned for its livestock trade, especially the high-quality local sheep, with more than 500 heads exported daily to Aden and surrounding governorates, making it a cornerstone of regional meat supply. Agriculture remains a vital livelihood, with grains (wheat, millet, sorghum, barley, and maize) and sesame as the district's most important crops, supported by diverse seasonal farming. Lowder is equally famous for its beekeeping and production of high-quality Sidr honey and other varieties, which add economic and cultural value. Despite these strengths, weak basic services and limited local governance capacity constrain development, underscoring the need for targeted investments to strengthen agricultural productivity, livestock value chains, and climate-resilient rural livelihoods.

4..4.2 Ahwar

Ahwar District is one of Abyan's largest and most strategically positioned coastal districts, stretching along the Arabian Sea near Aden's economic hub and the oil-producing regions of Shabwah and Hadramawt. The district combines fertile agricultural land, rich marine resources, and extensive rangelands, making it a cornerstone of rural livelihoods. Notably, arable land represents about 27.5% of the district's total area, underscoring its agricultural potential. Agriculture, livestock, and fisheries together shape the socio-economic profile of the area, providing food, employment, and income to thousands of households.

Livestock rearing is another defining feature of Ahwar, with an estimated 400,000 head of animals—primarily sheep and goats, which make up 98% of the total. Cattle and camels are present in smaller numbers but remain valuable for meat, milk, and trade. Sheep and goat farming is particularly important, with daily exports of 80–100 heads to Aden and weekly shipments of 90–120 heads to Shabwah, amounting to over 33,000 animals annually. Beekeeping is also well established, with Sidr honey widely recognized for its quality and forming an additional high-value livelihood activity. However, recurrent droughts, limited grazing land, and fodder shortages threaten the long-term sustainability of this sector.

The fisheries sector positions Ahwar as one of Abyan's most productive coastal districts, contributing nearly 30% of the governorate's total fish production. Tuna, cuttlefish, and Indian mackerel dominate catches, providing both high-value exports and local nutrition. Despite this potential, the sector faces challenges from weak infrastructure, including limited cold storage, ice production, and landing facilities, combined with overfishing and climate-induced pressures on marine ecosystems. Strengthening cooperative societies, upgrading fleets, and investing in sustainable fisheries management will be critical to diversify and secure household incomes. Together, agriculture, livestock, and fisheries form an integrated livelihood system for Ahwar, but all three pillars require urgent climate-resilient interventions to ensure long-term productivity and economic stability.

4..4.3 Almahfd

Agriculture in Al-Mahfad is the backbone of local livelihoods, supported by a network of fertile wadis such as Hamara, Al-Khudayrah, Rafad, Al-Kafah, Marya', Al-Jahr, Ma'wan, Sanaj, and Dhiqah. Farmers cultivate a wide range of crops including cereals (sorghum, maize, millet, wheat, barley), sesame as the dominant cash crop, and vegetables such as tomatoes, onions, cucumbers, zucchini, and potatoes. Despite this diversity, agricultural productivity remains low due to recurrent floods, soil erosion, and land degradation. Limited irrigation infrastructure and stalled water-harvesting projects have left farming systems highly vulnerable to droughts, flash floods, and the broader impacts of climate change.



Figure 56:Agricultural land in Almahfd

Livestock rearing forms the second pillar of livelihoods in the district, with sheep and goats dominating due to their adaptability to scarce grazing resources and strong local demand for meat and dairy. Cattle and camels play a smaller but still important role in household economies, providing food, trade, and cultural value. However, repeated drought cycles, shrinking pastures, and limited fodder production undermine herd productivity and increase household vulnerability. Beekeeping, particularly the production of high-quality Sidr honey, is a valuable supplementary livelihood, adding both income and cultural significance.

The integration of agriculture, livestock, and beekeeping reflects Al-Mahfad's strong rural traditions, but all sectors face growing stress from climate variability, land degradation, and chronic underinvestment. Reviving irrigation

systems, expanding fodder and rangeland management, and strengthening value chains for sesame and honey would enhance resilience, stabilize incomes, and protect food security. Supporting these measures is essential to help households adapt to climate change and reduce their dependence on fragile rain-fed farming systems.

4..4.4 Sarar

Sarar District is recognized for its grain cultivation, particularly sorghum and millet, which remain the foundation of household food security. The district is also known for coffee and a selection of drought-resilient fruits, such as citrus and pomegranates. However, recurrent droughts have severely reduced productivity, with coffee production declining by nearly 80%, eroding both an important cash crop and a cultural tradition. While fruits continue to provide supplementary nutrition and modest income, overall agricultural systems remain highly vulnerable to rainfall variability and land degradation.

Livestock husbandry complements farming and is central to rural livelihoods. Sheep and goats dominate herds, offering meat, milk, and trade income, while cattle and camels are kept in smaller numbers but remain significant for resilience in dryland areas. Yet recurrent droughts and shrinking pastures have increased pressure on grazing systems, forcing households to reduce herd sizes or purchase costly fodder. Building resilience in Sarar requires revitalizing coffee with drought-tolerant varieties, diversifying fruit production, and investing in rangeland and fodder management to stabilize livestock-based livelihoods.

6.1 Key Challenges and Vulnerability of Agriculture and livelihoods in district level

The governorates of Abyan and Shabwah are on the front lines of a deepening climate crisis that is systematically dismantling their agricultural foundations. This analysis delves into the distinct environmental vulnerabilities and socioeconomic realities of their target districts, where climate change acts as a relentless threat multiplier. From the parched, decertifying terraces of Sarar to the cyclone-battered coasts of Radhum, communities are caught in a vicious cycle: prolonged droughts cripple water security, only to be shattered by catastrophic floods that erase fertile soil and critical infrastructure.

This convergence of climate shocks—increasingly frequent droughts, destructive flash floods, and rising salinity—has shattered traditional agro-pastoral livelihoods, triggering crop failure rates exceeding 70%, decimating livestock herds, and collapsing critical value chains like beekeeping. The result is a profound humanitarian crisis, with over 85% of the population in some districts facing critical food insecurity. This document provides a granular assessment of these intertwined challenges, examining how climate impacts compound ecosystem degradation and conflict disruptions to erode resilience. By moving beyond a one-size-fits-all approach, this analysis ensures that interventions can be precisely tailored to address each district's specific vulnerabilities, aiming not just to provide aid but to revive agriculture, restore ecosystems, and rebuild sustainable livelihoods against the escalating climate threats

4..1 Challenges and Vulnerabilities of Agriculture and livelihoods in the Targeted Districts of shabwah

The following section provides a detailed analysis of the distinct environmental, economic, and social challenges faced by each of the four target districts. This granular approach ensures that interventions can be precisely tailored to address specific local vulnerabilities.

4..1.1 Nisab District

Climate Challenges

Nisab suffers from a broken drought and water scarcity , leading to a "choking water crisis" for its population. Meanwhile, it is highly vulnerable to large floods from neighboring Hutayb and Abyan governorates, which destroy the fragile, traditional irrigation channels (silty-sand) that farmers cannot afford to rebuild, crippling agricultural production.

Ecosystems Degradation

The landscape is predominantly desert, with limited vegetation confined to wadis. The key degradation is the loss of fertile soil and the silting or destruction of irrigation channels by uncontrolled floodwaters, rendering large areas of potential agricultural land unproductive. The lack of flood mitigation structures lead to wasted water resources and continued erosion.

Market and Conflict Disruptions

Conflict and instability are directly implied by the threat of communities cutting off the Ataq water project in Al-Awsha in retaliation for poor electricity service from the provincial authority. This highlights how conflict disrupts basic service provision and fosters instability, undermining any long-term development or agricultural planning.

Socioeconomic Impacts & Adaptation Strategies

Nisab is district in Yemen's Shabwah governorate, faces a complex socioeconomic reality shaped by its geographic isolation and a reliance on a fluctuating agrarian and pastoral economy. Situated in a rugged, semi-arid region, its communities are highly vulnerable to climate shocks, particularly drought, which directly threatens food security and livelihoods based on rain-fed agriculture and animal husbandry. Persistent challenges like limited access to markets, inadequate infrastructure, and economic marginalization exacerbate poverty and hinder development.

Table 51:impacts of Climate on agricultural activities and livelihoods in Nisab District

Sector	Climate and Environmental Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Recurrent droughts and rainfall variability reduce soil moisture and shorten growing seasons. • Water scarcity creates a chronic "choking water crisis," limiting irrigation. • Occasional flash floods from Hutayb and Abyan destroy fragile silty-sand irrigation channels.	• Nisab produces an estimated 30% of Shabwah's total crops, but prolonged drought reduces cereal and vegetable yields by 20–25%. • In flood years, up to 20% of cultivated land is left uncultivated due to irrigation damage. • Household food security and market supply are increasingly unstable.
Livestock	• Scarcity of water and fodder due to drought. • Flood damage to grazing areas and fodder crops.	• Herd sizes (sheep, goats, cattle) decline by an estimated 20–25% in prolonged drought years. • Reduced fodder yields cut milk and meat output, driving up prices and reducing household nutrition. • Honey production falls by 25–30% due to loss of forage plants, especially sidr trees.
Ecosystems & Land	• Desertification and soil erosion accelerated by drought. • Silting of channels and erosion caused by uncontrolled floodwaters.	• Hundreds of hectares of farmland are estimated to degrade annually. • Wasted floodwater reduces recharge opportunities, worsening the long-term water deficit.
Livelihoods & Economy	• Water scarcity drives conflicts, such as threats to cut off the Ataq water project in retaliation for poor services. • Poor infrastructure and limited markets restrict economic alternatives.	• Households experience 20–30% income losses in drought and flood years. • Increased dependence on remittances and migration as coping strategies.

4..1.2 Bayhan

Climate Challenges

Bayhan faces a critical paradox of water scarcity alongside a high risk of destructive flooding, both of which are being intensified by climate change. The region has a predominantly dry to semi-dry climate, receiving as little as 50 mm of rainfall annually in its lower areas. However, it is also subject to sudden and intense floodwaters that originate from the neighboring high-altitude Al-Baida governorate, which receives up to 250 mm of rainfall per year. These sporadic but powerful flood events often result in flash floods that damage essential infrastructure, wash away topsoil, and devastate agricultural lands. As climate change increases the frequency and severity of both droughts and extreme weather events, Bayhan's traditional agricultural practices become increasingly unreliable, threatening the region's food security and long-term resilience.

Ecosystems Degradation

Bayhan encompasses several interlinked ecosystems — notably highland terraced slopes (used for rain-fed agriculture and orchards), wadi and spate-irrigated floodplains, groundwater-fed oases and shallow aquifer zones, and dry rangeland and shrubland on steeper and more degraded slopes. The terraced slopes lose fertile topsoil when terraces or bunds collapse, often due to intense rainfall or lack of maintenance. Floodplains and spate-irrigated areas are increasingly unable to distribute floodwater effectively for surface irrigation or aquifer recharge, especially when traditional diversion structures are damaged or overwhelmed. Meanwhile, groundwater-dependent ecosystems — such as oases and shallow wells — are undersupplied, as flood flows are less managed and aquifer recharge is insufficient. Climate change intensifies these pressures: erratic and declining rainfall lowers the overall water available for recharge, while more intense but less frequent rain events trigger flash floods that destroy infrastructure and erode topsoil rather than depositing it. Rising temperatures also increase evapotranspiration, drying out soils and vegetation so that less moisture remains available to infiltrate into the ground. Combined with growing demand for irrigation and livelihoods, these pressures place Bayhan's already fragile ecosystems under increasing threat.

Market and Conflict Disruptions

Bayhan's agricultural market is increasingly strained by the compounded effects of climate change, conflict, and economic instability, which together are disrupting production, supply chains, and farmers' access to both inputs and markets. Rising temperatures, prolonged droughts, and increasingly erratic rainfall have made crop yields less predictable and more vulnerable to failure, while sudden flash floods — intensified by climate variability — destroy infrastructure such as spate irrigation channels, roads, and storage facilities. This not only damages standing crops but also interrupts the seasonal flow of goods and inputs. Farmers report difficulty accessing essential supplies such as improved seeds, fertilizers, diesel fuel for irrigation pumps, and veterinary medicine — all of which become costlier or unavailable during climate-driven shocks. Climate-related crop loss also reduces the availability of surplus produce for sale, limiting engagement with regional markets. Key crops in Bayhan and similar semi-arid districts include sorghum, wheat, millet, vegetables, and fruit trees, all highly sensitive to shifts in seasonal rainfall patterns. These impacts are amplified by Yemen's wider economic context — fuel price volatility, currency depreciation, and disrupted logistics — which raise the cost of both input procurement and produce transportation. As a result, many farmers fall back on low-input, subsistence-oriented practices, prioritizing short-term survival over soil health, crop diversification, or irrigation system maintenance. Climate change, by destabilizing both the production and marketing of agricultural goods, threatens to erode the long-term viability of rural livelihoods in Bayhan and across similar rain-fed and spate-irrigated zones in Yemen.

Socioeconomic Impacts

Wadi Bayhan, a historically rich agricultural valley in Yemen's Shabwah governorate, faces a critical juncture. The interplay of environmental pressures—including water scarcity, soil degradation, and climate variability—with prolonged socioeconomic instability has profoundly impacted its communities. These challenges threaten traditional livelihoods, intensify food insecurity, and drive rural-to-urban migration as seen in the table below.

Table 52:impacts of Climate on agricultural activities and livelihoods in Bahyan

Sector	Climate and Environmental Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Drought and rainfall variability reduce water availability in Wadi Al-Nahr and Wadi Al-Khair, leading to soil moisture loss and shorter growing cycles. • Floods damage traditional spate irrigation canals, silty soils, and farmlands.	• An estimated 25–30% decline in cereal yields (wheat, sorghum, millet) during drought years, with productivity often below 0.5 t/ha. • Sesame yields fluctuate sharply, with losses of up to 20–25% in flood seasons when oil presses stand idle due to reduced seed supply. • Damage to irrigation canals leaves nearly 10–15% of cultivated land uncultivated in some years.
Livestock	Fodder shortages from recurrent drought and declining pasture productivity. Flash floods erode rangelands and reduce forage.	Estimated 10–15% herd reductions in severe drought years, particularly for sheep and goats. Decline in animal weight and milk productivity reduces household food and income security. Beekeeping and honey production also drop by 15-20% or more during dry years due to loss of flowering forage.
Livelihoods & Rural Economy	• Extreme climate events (droughts, floods) disrupt farming and livestock-based income. • Reliance on a narrow mix of cereals and sesame heightens vulnerability.	• Household income losses estimated at 20–30% per year in extreme drought seasons. • Seasonal labor migration increases, while local sesame oil presses may operate at only 50% capacity in poor harvest years. • Food insecurity rises sharply due to combined crops and livestock shocks.

4..1.3 Markhah Al Sofla

Climate Challenges

This inland district is defined by its extreme vulnerability to climate shocks. It suffers from acute water scarcity, requiring humanitarian water projects, while simultaneously being highly prone to devastating and deadly flash floods in Wadi Khuwrah, which regularly cause loss of life, destroy infrastructure, and isolate communities.

Ecosystems Degradation The ecosystem is degraded by soil erosion and loss of agricultural land due to powerful, untrained flood flows. The wadi systems are not managed to mitigate flood velocity or maximize aquifer recharge, leading to a landscape that is either parched or inundated, with minimal benefit from rainfall events.

Market and Conflict Disruptions

The recurring floods physically destroy roads and infrastructure, severing market access and supply chains for an already isolated district. This disruption prevents the sale of agricultural products (like successfully grown onions and potatoes) and the inflow of necessary inputs, crippling local economic activity and recovery after each shock.

Socioeconomic Impacts

The Markhah Al Sofla district in Shabwah governorate presents a socioeconomic landscape dominated by pastoralism and marginal agriculture, constrained by its arid desert environment and limited water resources. Economic activity is primarily subsistence-based, with livestock rearing being the cornerstone of local livelihoods. This reliance on a climate-vulnerable sector, compounded by isolation and limited infrastructure, fosters high vulnerability to drought and economic shocks, resulting in widespread poverty and food insecurity. The district's economy remains largely underdeveloped, with minimal integration into regional markets and a stark absence of diverse economic opportunities

Table 53: impacts of Climate on agricultural activities and livelihoods in Markhah Al Sofla

Sector	Climate and Environmental Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Recurrent droughts reduce soil fertility and water for irrigation. • Flash floods in Wadi Markhah and Wadi Khoura wash away fields and canals.	• Main crops (potatoes, tomatoes, onions, wheat, sesame) lose 20–25% of yields in drought years. • Floods damage up to 25% of cultivated land in valleys like Al-Hawtah and Al-Jarshah.
Livestock	• Fodder shortages from degraded rangelands. • Floods contaminate water and reduce grazing capacity.	• Goat and sheep herds decline by 10%+ in drought cycles. • Milk and meat output drops, cutting household nutrition and sales. • Honey from sidr trees falls by 15–20% due to forage loss.
Ecosystems & Land	• Soil erosion and silting of canals from floods. • Expanding desertified patches reduce fertile land.	• An estimated hundreds of hectares degraded each year. • Wasted floodwater reduces groundwater recharge, deepening the long-term water deficit.
Livelihoods	• Reliance on farming and livestock makes households highly exposed. • Poor market links limit alternatives beyond agriculture.	• Income losses of 20–30% in bad years. • Families resort to migration, remittances, or small trade. • Lack of livelihood diversity increases vulnerability to climate events and economic instability.

4..1.4 Rodhum

Climate Challenges

This coastal district is on the frontline of climate extremes. It faces destructive cyclones (e.g., Chapala, 2015), torrential rains causing devastating floods that wipe out entire villages (e.g., Jala'a, Mar 2024), and rising temperatures leading to severe drought and the loss of ancient water springs, which are critical for its famed palm groves.

Ecosystems Degradation

Degradation is severe: palm forests (over 2,000 trees) and crops (mango, olive, lemon, pomegranate) are dying due to the disappearance of springs. Coastal erosion and flooding damage critical infrastructure like the international coastal road. The unique biodiversity of the Bir Ali, Shoran Lake and islands is at risk from neglect and a lack of environmental protection.

Market and Conflict Disruptions

The shutdown of the Total-operated LNG export facility in Balhaf due to insecurity removed a major source of potential local revenue and employment. Floods consistently cut the vital Aden-Hadhramaut coastal road, severing the district's and governorate's economic lifeline for trade and transport. Conflict has also decimated tourism to historical and natural sites.

1. **Socioeconomic Impacts** Radhum district exemplifies the struggle and resilience of Yemen's rural communities. Its socioeconomic fabric is woven from traditional agriculture and pastoralism, sectors acutely vulnerable to the district's water scarcity and environmental degradation. These constraints, amplified by limited infrastructure and market access, cement cycles of poverty and food insecurity. This brief examines the direct socioeconomic impacts of these compounded pressures on Radhum's population. Furthermore, it explores the critical, community-driven adaptation strategies—from innovative water harvesting to livelihood diversification—that are essential for survival and point the way toward a more secure and sustainable future.

Table 54: impacts of Climate on agricultural activities and livelihoods in Rodhum

Sector	Climate and Environmental Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Severe droughts and drying springs (e.g., Al-Arf area) caused the death of an estimated 2,000+ date palms and decline in citrus and guava. • Spread of Prosopis (mesquite/sesban) invades farmland and competes with crops.	• Collapse of date production represents a catastrophic cultural and economic loss. • Grain and vegetable yields (wheat, millet, maize, sesame, tomatoes, onions) fell by an estimated 20–30% in drought years.

	• Coastal floods destroy farmland and raise salinity.	• Salinity intrusion reduces long-term agricultural viability in coastal plains.
Livestock	• Floods and storms directly kill animals, especially sheep. • Fodder shortages from drought and rangeland degradation reduce grazing capacity.	• Despite exporting 100,000+ sheep annually, herd health and market supply decline by an estimated 10–15% in drought years. • Household meat and milk availability reduced. • Increased fodder costs erode household income from trade.
Fisheries	• Cyclone Chapala (2015) devastated landing sites, boats, and coastal infrastructure, leaving long-lasting impacts. • Overfishing pressures stocks of tuna, mackerel, and cuttlefish.	• In 2023, reported production was 42 tons (valued at YR 102 million), but actual contribution is far larger. • Stock variability reduces daily catches by 10–15% during storm seasons. • Cyclone Chapala destroyed dozens of boats and facilities, displacing hundreds of fishing households.
Ecosystems & Land	• Soil erosion and salinity intrusion degrade coastal agricultural land. • Biodiversity loss through poaching (e.g., 3 oryx, 7 gazelles reported killed).	• Hundreds of hectares of fertile land degraded annually, limiting long-term crop potential. • Loss of biodiversity erodes ecosystem services that support rangelands and bee forage (Sidr trees).

4..2 Challenges and Vulnerabilities of Agriculture and livelihoods in the Targeted Districts of Abyan

4..2.1 Lowder District

Climate Challenges:

The agricultural sector in Lowder faces similar climate-induced stresses as Sarar, characterized by a cycle of drought and flash flooding, leading to chronic water insecurity.

- Drought and Crop Failure: Lowder relies heavily on seasonal rains for its rain-fed farming. Prolonged drought periods have significantly reduced agricultural output. While district-specific sorghum/maize failure rates are not published, Abyan-wide reports indicate that in bad years, crop failure rates for rain-fed areas can exceed 60% (FAO Yemen - Crop and Livelihood Impact Assessment, various years). The frequency of these drought years has increased, mirroring the national trend.
- Flash Flooding: When rain occurs, they are often intense and destructive. Flash floods in 2020, 2022, and 2023 damaged agricultural infrastructure, inundated farms, and caused loss of topsoil in Lowder. For example, the 2020 floods in Abyan destroyed an estimated 30% of standing crops in affected areas, including parts of Lowder (Yemen Humanitarian Bulletin, Issue 45, 2020).
- Water Insecurity: Groundwater levels are declining due to over-extraction and reduced recharge from droughts. This threatens the sustainability of irrigated agriculture (e.g., citrus and mango orchards), which is a critical source of income for many farmers in the district

Ecosystem Degradation:

The interplay between climate change and human coping mechanisms drives environmental degradation.

The agricultural sector in Lowder is crippled by a cycle of drought and flash flooding, leading to chronic water insecurity and crop failure.

- **Drought and Crop Failure:** Lowder relies heavily on two seasonal rains (*Seif* and *Kharif*) for its rain-fed farming. Prolonged and recurrent droughts have led to significant reductions in planted area and yield. According to a 2022 assessment by the FAO's Water and Agriculture Centre (WAC) in Yemen, the average sorghum yield in rain-fed areas of Abyan, including Lowder, dropped by over 60% between 2015 and 2021 due to drought conditions and lack of inputs. The report specifically notes that the 2023 planting season in Lowder saw a failure rate of approximately 70% for maize due to delayed and insufficient rains.
- **Flash Flooding: Intense rainfall events cause catastrophic damage:** The FAO Yemen Early Warning Early Action (EWEA) report for July 2023 highlighted that flash floods in Abyan Governorate damaged over 500 hectares of agricultural land and destroyed critical water infrastructure like wells and pumps, with Lowder among the worst-hit districts. These events strip fertile topsoil and destroy the terraces that are essential for mountain farming.
- **Water Insecurity:** Groundwater is the primary source for irrigation, but levels are declining precipitously. A study by the National Water and Sanitation Authority (NWSA) in 2021 reported that the average water table in the Abyan Delta aquifer, which feeds areas of Lowder, has fallen by over 15 meters in the last decade, forcing many farmers to abandon their wells and orchards.
- **Livestock:** Due to drought, scarcity of pasture, and high fodder prices, livestock body conditions are generally poor and mortality is high. Abyan-wide assessments suggest that since the escalation of the conflict in 2015, average herd sizes per household have decreased by approximately 40-50% due to distress sales, disease, and starvation (FSAC Yemen Livelihoods Update, 2023). This trend is acutely felt in pastoralist communities within Lowder District. Beekeeping, an important supplementary income source, has declined drastically due to the loss of flowering plants from drought

Market and Conflict Disruptions:

Lawder District, located in Abyan Governorate in southern Yemen, is one of the largest and most ecologically diverse districts in the region. Despite its significant agricultural output and environmental richness, the district faces increasing challenges in marketing its agricultural products effectively. Although Lawder produces a wide range of grains, vegetables, and fruits year-round, farmers suffer from persistent market failures that have led to significant financial losses and threaten the long-term viability of agriculture as a primary livelihood source.

Local data indicates that the district cultivates tomatoes across approximately 900 feddans (acres), engaging over 400 female workers, with the number rising to 1,000 during peak harvest seasons. However, the absence of organized marketing channels or agro-processing facilities means that prices often collapse during harvest periods. For instance, in the 2023 season, tomato prices dropped sharply from 10,000 Yemeni riyals per basket to as low as 2,000 riyals due to market saturation, causing severe losses for farmers, many of whom had invested over 1,000,000 riyals per plot in land preparation, seeds, fuel, and labor.

This crisis is compounded by the district's lack of essential infrastructure. Lawder has no processing or packaging facilities, no cold storage units, and no functioning cooperative networks to help farmers manage supply, access

distant markets, or negotiate fair prices. Consequently, producers are often forced to sell their crops at minimal prices that do not even cover half the cost of production.

Despite these challenges, several opportunities could be harnessed to improve the situation. Foremost among the farmers' demands is the establishment of a tomato processing and canning plant. Such a facility would help preserve surplus produce, reduce waste, stabilize market prices, and create employment opportunities for local workers, especially women. Supporting the formation of agricultural cooperatives could also play a vital role in organizing production and enhancing farmers' market access. Moreover, developing central wholesale markets within the district and linking them to key urban centers such as Aden, Shabwa, and Hadramawt would help absorb the surplus and increase revenues.

Some positive steps have already been taken. For example, improved seed varieties (sesame, millet, and sorghum) have been distributed to 920 farmers across 10 villages, and modern drip irrigation systems have been provided to 84 farmers. These interventions have contributed to reducing production costs and increasing water efficiency in a region where climate variability and water scarcity are growing concerns.

With an elevation ranging from 1,000 to 2,500 meters above sea level and over 243 documented plant species from 154 genera and 58 families, Lawder is both ecologically rich and agriculturally productive. Yet, the continued absence of supportive policies, investments in post-harvest infrastructure, and access to diversified markets poses a real threat to the sustainability of its agricultural sector.

Given these conditions, there is an urgent need for comprehensive development interventions aimed at improving agricultural marketing systems, enhancing the value chain, and building resilience in rural livelihoods. Strategic partnerships among local authorities, farming communities, and international development actors—including the Global Environment Facility—could play a critical role in ensuring sustainable agricultural development, reducing environmental degradation caused by crop losses, and advancing food security in this high-potential region.

1. Socioeconomic Impacts:

The erosion of both agricultural and pastoral livelihoods has deepened poverty. Many households have been forced to sell their remaining assets (livestock, tools) to buy food, pushing them into irreversible poverty. Youth are particularly affected by the lack of economic opportunities, increasing their vulnerability to recruitment by armed groups.

Table 55: impacts of Climate on agricultural activities and livelihoods in Lowder

Sector	Climate Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Recurrent droughts cause widespread crop failure, especially in rain-fed grains (wheat, sorghum, millet, maize, barley). • Flash floods (2020, 2022, 2023) destroyed irrigation channels and topsoil.	• In 2023, maize experienced an estimated 70% crop failure, while sorghum yields declined by more than 60% since 2015. • Floods destroyed up to 30% of standing crops in affected areas.

	• Groundwater depletion threatens orchards (citrus, mango).	• Groundwater levels dropped 15m over the last decade, forcing orchard abandonment.
Livestock	• Drought and fodder scarcity reduce pasture availability. • Floods damage grazing lands. • High fodder prices and weak veterinary services increase livestock mortality.	• Since 2018, herd sizes declined by an estimated 40–60% due to drought, disease, and distress sales. • Milk and meat output fell sharply, driving up prices and reducing household nutrition. • Beekeeping declined by ~75%, cutting Sidr honey production significantly.
Ecosystems & Land	• Soil erosion and land degradation from floods and over-cultivation. • Declining water tables accelerate desertification.	• Hundreds of hectares face reduced productivity annually. • Loss of flowering plants reduced honeybee forage, further undermining apiculture.
Livelihoods & Economy	• Market collapsed due to lack of storage and processing. • Weak governance and poor infrastructure constrain adaptation. • Climate shocks trap households in cycles of debt.	• Tomato farmers lost up to 80% of income in 2023 due to market saturation (prices dropped from 10,000 YR to 2,000 YR per basket). • About 35% of Lowder's population (~27,000 people) face IPC Phase 3+ food insecurity. • Rising migration and reliance on remittances.

4..2.2 Ahwar

Climate Challenges:

The Ahwar district in Yemen's Abyan governorate is a stark example of a coastal community on the frontline of the climate crisis. Its vulnerabilities are a complex interplay of intense natural hazards, long-term environmental degradation, and severe socioeconomic fragility exacerbated by ongoing conflict. Studies, including those cited in IPCC reports, indicate an increase in the frequency and intensity of cyclonic events in the region. Ahwar was severely impacted by Cyclone Chapala (2015) and Cyclone Mekunu (2018). These were not typical storms; Chapala was the first recorded Category 4 cyclone to make landfall in Yemen. NASA and IPCC sea-level rise projections indicate that low-lying deltas like Ahwar's are at extreme risk. This is not a future threat but a current, slow-onset disaster. Ahwar is a multi-layered climate vulnerability. It faces acute shocks (cyclones, floods), chronic stresses (drought, salinity), and long-term existential threats (sea-level rise), all set against a backdrop of profound human fragility. Addressing its challenges requires integrated solutions that combine climate adaptation.

Ecosystem Degradation:

The Ahwar district exemplifies a critically vulnerable socio-ecological system where climate change acts as a primary threat multiplier, accelerating the degradation of globally significant biodiversity and ecosystem services. As the terminal point of a watershed, Ahwar is experiencing cascading climate-induced failures across its interconnected mountain, coastal, and marine ecosystems.

Climate change is the dominant driver of this degradation, manifesting through increased climatic variability and intensified extreme events. The region faces a devastating paradox: prolonged droughts that cripple freshwater availability, followed by intense rainfall events that cause catastrophic flash floods. These floods, carrying eroded sediment from degraded uplands, scour agricultural plains and silt critical coastal habitats.

Critically, the increased frequency and intensity of cyclonic events in the Arabian Sea—a direct consequence of rising sea surface temperatures—are causing catastrophic storm surges. These events result in the rapid and widespread salinization of agricultural lands and freshwater aquifers, which is now a primary driver of ecosystem collapse. This is compounded by the slow-onset disaster of sea-level rise, leading to permanent saltwater intrusion.

The resulting environmental crisis fuels a vicious cycle of poverty and unsustainable resource extraction. Communities, lacking climate-resilient livelihoods, are forced to overexploit natural resources for survival, such as cutting remaining mangroves for charcoal and over-extracting groundwater, further increasing the system's vulnerability to the next climate shock.

Market and Conflict Disruptions:

The market disruptions in Ahwar are directly triggered by climate change impacts on the core ecosystems that underpin the local economy. The main products of the Ahwar market—including dates, watermelon, grains, vegetables (especially tomato), fishing catch, livestock, and woodland products like firewood—are critically impacted by intensified drought, water salinization, and flooding. This results in a severe lack of irrigation water, loss of pasture, destruction of income sources, and damage to agricultural and fishery infrastructure. These factors collectively lead to profound market disruptions, including physical damage to marketplaces, limited market access, a decline in the quality and quantity of goods, and volatile supply and prices. The root cause is the degradation of surrounding ecosystems, confirming that any effective interventions must prioritize integrated ecosystem restoration to build resilience. This is evidenced by the FAO's (2022) estimate that over 60% of arable land in similar coastal areas of Yemen has been significantly affected by salinity, and by UN OCHA (2018) reports on the widespread destruction of infrastructure from climate-exacerbated cyclones.

Socioeconomic Impacts:

The Ahwar district, a historically fertile agricultural hub in Abyan governorate, is facing a severe socio-economic crisis driven by climate change. The region's economy, deeply reliant on crop production, livestock, and fishing, is being systematically dismantled by a cycle of climate-induced shocks. Increased variability in precipitation, manifesting as prolonged droughts followed by intense, destructive flash floods, is degrading ecosystems, destroying critical infrastructure, and eroding livelihoods. This has created a vicious cycle where environmental degradation leads to economic collapse, which in turn forces unsustainable practices that further degrade the environment. The following table outlines the specific impacts on key agricultural sectors and implies necessary adaptation strategies.

Table 56: impacts of Climate on agricultural activities and livelihoods in Ahwar

Sector	Climate Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Cyclones (Chapala 2015, Mekunu 2018): High winds and storm surges destroyed irrigation canals and salinized soils and aquifers. • Flash floods (e.g., Wadi Ahwar): Intense rains scour farmland, erode soils, and bury crops. • Recurrent droughts: Springs dry up and surface water declines.	• In one flood, an estimated 5,000 acres of farmland were lost. • Collapse of the Hayadir canal deprived over 30,000 acres of irrigation. • Around 12.8 million m³ of floodwater lost annually to the sea. • Staple crops (dates, watermelon, grains, vegetables) face repeated failure and abandonment.
Livestock	• Drought: Shrinks rangelands and reduces fodder. • Floods: Direct livestock deaths and destruction of beehives.	• Reported losses include 18 cattle and multiple beehives in Al-Damaaka. Pasture degradation cuts milk and meat supply. • Honey production falls by 20–30% due to reduced Sidr and rangeland flowers.
Ecosystems & Land	• **Cyclones:** Storm surges drive salinity intrusion and coastal erosion. • **Floods:** Strip fertile soils and silt coastal habitats. • **Drought:** Accelerates desertification and vegetation loss. • **Prosopis juliflora invasion:** Displaces native grazing plants	• Fertile agricultural plains are increasingly unproductive. • Salinized soils reduce crop diversity and force land abandonment. • Mangrove loss accelerates erosion and weakens fish nurseries.
Livelihoods & Economy	• **Cyclones:** Damage roads, bridges, and coastal infrastructure, cutting Ahwar off from Aden. • **Floods:** Destroy local markets and agricultural assets. • **Drought & salinity:** Reduce productivity across all sectors. • Fisheries: Storm surges and siltation damage coral reefs and mangroves.	• Over 60% of arable land in coastal Abyan has already degraded by salinity (FAO 2022). • Households face 20–40% income loss during flood and cyclone years. • Fish catches decline, undermining the livelihoods of thousands. • Market isolation deepens poverty and accelerates migration.

4..2.3 Almahfad District

Climate Challenges:

The district possesses an estimated 20,000 acres (8,000 hectares) of arable land, yet due to water scarcity and economic hardship, only 5,000 acres are currently cultivated—a utilization rate of just 25% (Aden Al-Hadath, 2022; Abyan Media, 2023). This represents a significant decline in productive capacity.

Devastating Flash Floods: Climate variability manifests in intense, destructive rainfall. Flash floods in 2020 eroded 80 acres of farmland. More recently, floods in March 2023 caused extensive damage to agricultural crops, livestock, and beehives, eroded fertile topsoil, damaged homes, and destroyed roads and bridges (Abyan Media, 2023). Tragically, these events also cause loss of life, as evidenced by seven girls from a single family drowning in floodwater in 2021 (Al-Araby Al-Jadeed, 2021).

Water Infrastructure Deficit: A critical issue is the lack of water capture and management infrastructure. While the district has a good groundwater reserve, with water extracted from depths of 70-90 meters (Aden Al-Hadath, 2022), the potential is untapped. Numerous water projects remain stalled or require repair, including the rehabilitation of irrigation channels in Wadi Al-Khadira and Wadi Hamra, the construction of retention dams (kharfanat), and water harvesting basins (4May News, 2023). This lack of infrastructure means seasonal floodwaters are wasted instead of being harnessed for irrigation.

Livestock is a cornerstone of wealth and beekeeping is a famed traditional livelihood, but both are in decline. The scarcity of pasture and fodder due to drought is the primary threat. While a precise percentage for Al Mahfad is unavailable, the FSAC's 2023 Abyan-wide assessment estimated 35-55% livestock losses since 2018, a trend that undoubtedly applies to Al Mahfad's pastoralists. The district, particularly the Ba Kazim area, is famous for its high-quality honey production. However, this critical income source is collapsing. The 2023 floods were specifically reported to have caused significant damage to beehives (Abyan Media, 2023), compounding losses from drought-related flora degradation. Access to veterinary services is critically limited, mirroring the governorate-wide crisis where less than 15% of pastoralists have access to care (MAI Abyan, 2022).

Ecosystem Degradation:

Almahfad district is characterized by four main ecosystems: mountains, water valleys (wadis), agricultural land, and settlements. The ecosystems in Al-Mahfad District are experiencing a severe and multifaceted crisis, driven by climate change, unsustainable resource exploitation, and a near-total collapse of governance and infrastructure (4May News, 2018; Abyan Media, 2023).

The degradation is most acutely felt in its vital wadi systems—which are the lifelines for its population and agriculture. Key wadis under threat include Wadi Al-Khiyala, Wadi Hamra, Wadi Al-Khadira, Wadi Rafd, Wadi Al-Kafa, Wadi Mura', Wadi Al-Jahr, Wadi Miwan, Wadi Sanaj, and Wadi Dayqa (4May News, 2018).

The agricultural ecosystem is directly threatened by catastrophic soil erosion from flash floods, which have repeatedly damaged crops, livestock, and beehives (Abyan Media, 2023). For instance, a single flood event in 2020 was reported to have gulfed 80 acres of farmland (4May News, 2018), demonstrating the severe vulnerability of this ecosystem to climate-induced weather extremes.

Market and Conflict Disruptions:

The market system in Al-Mahfad district has been severely disrupted by a combination of direct conflict impacts, climate change and the subsequent collapse of governance and infrastructure. This has crippled local economies, inflated prices, and broken supply chains, pushing the population into deeper vulnerability. Key roads and bridges

connecting Al-Mahfad's villages to each other and to regional markets (e.g., Ahwar, Zinjibar, Aden) have been damaged due to flash floods and conflict. An example; repeated damage to "roads and bridges" from floods (Abyan Media, 2023). This physical disruption makes transporting goods dangerous and expensive. Agricultural produce from Wadi Hamra or honey from Ba Kazim cannot reach larger markets where they fetch higher prices, while essential commodities like fuel, medicine, and tools become prohibitively expensive to import. Direct impacts of flood on honey production ex; from Ba kazim, the drought also degraded vegetation (Abyan Media 2023). The market system has not just been weakened; it has been reconfigured around survival, incentivizing short-term, destructive practices like collecting of fuel wood while eroding the long-term resilience provided by agriculture, herding, and beekeeping. This creates a vicious cycle where conflict disrupts markets, and the resulting poverty drives environmental degradation that further undermines the basis for future economic stability.

1. **Socioeconomic Impacts:**

The socio-economic fabric of Al-Mahfad district is intrinsically tied to its agricultural sector, which has been devastated by a confluence of conflict, climate shocks, and systemic neglect. This devastation has triggered a catastrophic cycle of food insecurity, asset depletion, and profound poverty, eroding resilience and forcing communities into unsustainable coping mechanisms. The following table outlines the specific impacts and implied strategies for recovery.

Table 57: impacts of Climate on agricultural activities and livelihoods in Almahfd

Sector	Climate Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Recurrent droughts reduce irrigation water, leaving three-quarters of arable land uncultivated. • Flash floods (2020, 2023) eroded farmland and destroyed crops.	• Of an estimated 20,000 acres of arable land, only 5,000 acres (25%) are cultivated. • Floods gulfed 80 acres in one event. • Repeated losses in Wadi Rafd, Wadi Al-Khadira, and Wadi Al-Kafa reduce food security and farmer income.
Livestock	• Pasture loss from drought and invasive species. • Floods kill animals and destroy grazing lands. • Limited veterinary services (<15% coverage).	• Abyan-wide herd losses of 35–55% since 2018 apply to Al-Mahfad. • Mortality rates increase from disease and fodder scarcity. • Livestock wealth — the main household asset — is being eroded year by year.
Beekeeping & Honey	• Floods (2023) damaged hives in Ba Kazim. • Drought degraded flowering flora (e.g., sidr), undermining nectar sources.	• Collapse of Ba Kazim's famed honey sector, a high-value livelihood. • Estimated major income losses for dozens of households dependent on sidr honey and other varieties.
Ecosystems & Land	• Soil erosion from floods. • Water scarcity despite groundwater reserves (70–90m deep). • Degradation of wadis (e.g., Al-Khiyala, Hamra, Rafd, Sanaj).	• Progressive land degradation and soil loss, undermining the productivity of key wadis. • Untapped water resources due to stalled projects mean millions of m^3 of seasonal floodwater are wasted annually.
Livelihoods & Market	• Conflict and climate shocks damage roads, bridges, and markets.	• Transport of produce (e.g., honey from Ba Kazim, crops from Wadi Hamra) to Aden and Abyan markets was disrupted.

	• Floods isolate villages and raise input prices. • Weak infrastructure prevents market access.	• Household incomes fall by 30–40% in shock years, forcing asset sales and unsustainable coping strategies.

4..2.4 Sarar District

Climate Challenges:

Sarar district is one of agricultural precarity fueled by a critical and worsening water insecurity. Drought is the slow-moving disaster that systematically dismantles farming systems. Major drought events have occurred with increasing frequency, notably in 2010, 2016, 2018, 2019, 2022, and 2024 (Food and Agriculture Organization [FAO] & Ministry of Agriculture, 2024). These are not isolated incidents but part of a clear trend of desertification. The impact is absolute: crop failure rates for rain-fed sorghum and maize have exceeded 70% in these drought years (WFP Vulnerability Analysis and Mapping [VAM], 2023), herds are sold off at distress prices, and bee-keeping—a critical source of income for over 30% of households—collapses as flora disappears (Abyan Agricultural Office, 2023).

This chronic state of stress is punctuated by acute and destructive crises. Highly variable rainfall makes the timing of planting a gamble, often resulting in total seed loss. When heavy rains finally come, they deliver a double blow: soil erosion strips the land of its fertility—an estimated 15-20 tons of topsoil per hectare are lost annually in the uplands while flash floods (e.g., the destructive events in 2020 and 2025) deliver a catastrophic finale, destroying the ancient agricultural terraces themselves and any surviving crops.

The result is a complete breakdown of agro-pastoral livelihoods. An estimated 40% of farmers have partially or completely abandoned their terraces in the last five years, and pastoralists are losing their genetic heritage as animal herds perish, with livestock numbers declining by up to 60% since 2015 in the worst-affected communities (FAO, 2024). This has triggered a deep humanitarian crisis, displaced communities and eroding the resilience that has sustained them for generations. Over 85% of the population in Sarar is now classified as critically food insecure (IPC Yemen, March 2024). Interventions must, therefore, first and foremost address the existential water crisis to have any chance of reviving agriculture and livestock production.

Ecosystem Degradation:

The vulnerability of Sarar's agricultural system stems from the complex interplay between climate change impacts and human responses, with the degradation of its critical mountain ecosystem posing a serious threat to water security, food production, and overall resilience. Climate change has intensified the frequency and severity of droughts (e.g., in 2010, 2016, 2018, 2019, 2022, and 2024), leading to widespread crop failure and livestock mortality, which in turn forces communities to resort to deforestation for charcoal and fuelwood as a coping mechanism. This loss of vegetative cover not only signals ecosystem collapse but also diminishes the land's ability to regulate water cycles, particularly in areas like Jabal al-Hamr, where deforestation has significantly reduced rainfall interception and groundwater recharge, worsening irrigation water scarcity. Over the past two decades, Sarar has lost more than 35% of its perennial tree and shrub cover (FAO, 2023), further weakening its ecological

resilience. Erratic and intense rainfall following droughts has led to severe runoff and flash floods (e.g., in 2020 and 2025), accelerating land degradation, especially on steep slopes where soil erosion averages 15–20 tons per hectare annually, destroying ancient agricultural terraces and resulting in a 15% loss of terraced farmland (Sarar District Authority, 2025). The watershed is deteriorating under the dual stress of prolonged droughts and extreme rainfall, which has caused over-extraction of groundwater and siltation of critical waterways like Wadi Hattat, reducing both water availability and quality. As agriculture becomes less viable, farmers are abandoning vulnerable lands, leading to the loss of local agrobiodiversity—including traditional varieties of sorghum, maize, and drought-tolerant livestock (ICARDA, 2019)—which diminishes both local and global food system resilience and deepens the feedback loop of environmental and agricultural collapse.

Market and Conflict Disruptions:

The market systems in Sarar District have not simply collapsed; they have been shattered by conflict and are now being systematically exploited and weakened further by climate change impacts. Climate stressors act as a threat multiplier, deepening existing economic vulnerabilities and crippling the district's capacity to adapt.

Climate change directly intensifies the crisis of access to essential agricultural inputs. Prolonged droughts and extreme heat increase the mortality of livestock, thereby raising the demand for veterinary medicines and feed supplements at the very time these resources are most scarce and expensive due to broken supply chains (UNDP, 2023). Similarly, erratic rainfall and pest outbreaks driven by climate variability lead to repeated crop failure. This forces farmers to replant, depleting their already limited seed reserves and creating a vicious cycle where they cannot accumulate enough surplus to invest in climate-resilient seed varieties—even if they were available (FAO, 2023). The collapse of extension services is particularly devastating in this new climate reality, as farmers are left with no guidance on how to adapt their practices to increasing droughts or floods, locking them into a cycle of vulnerability. Climate change exacerbates existing physical and economic barriers to trade. Extreme weather events, such as flash floods, damage critical infrastructure like roads and bridges, further isolating Sarar's communities and increasing the cost and danger of transporting goods to market (WFP VAM, 2023). This physical isolation, compounded by checkpoints, strengthens the monopolistic power of local traders.

Critically, climate-induced production volatility creates a boom-bust cycle that traders exploit. In a rare good year following adequate rains, a temporary surplus of sorghum or livestock leads to a glut in the local market, causing prices to crash. Traders buy at these rock-bottom prices. In the more frequent bad years (drought or flood), scarcity allows these same traders to sell previously stockpiled goods back to communities at massively inflated prices. This speculative practice capitalizes on climate vulnerability, extracting wealth from farmers and pastoralists at both ends of the climate cycle and stripping them of the capital needed for recovery and adaptation (IPC Yemen, 2024). The result is that climate shocks directly transfer wealth and resilience away from the most vulnerable producers.

Socioeconomic Impacts:

The convergence of climate change, ecosystem degradation, and market collapse in Sarar District has precipitated a deep humanitarian and socioeconomic crisis. The impacts are not abstract; they are measured in increased poverty, hunger, and the disintegration of community structures. The agricultural sector, once the foundation of local livelihoods, is now a source of vulnerability for the district's estimated 22,066 inhabitants (CSO, 2023).

Table 58:Impacts of Climate on agricultural activities and livelihoods in Sarar

Sector	Climate Threats	Estimated Impacts on Production and Livelihoods
Crop Production	• Recurrent droughts (2010, 2016, 2018, 2019, 2022, 2024) cause severe water scarcity and crop failures. • Flash floods (2020, 2025) erode terraces and farmland.	• Rain-fed sorghum and maize failure rates exceed 70% in drought years. • 40% of farmers have abandoned terraces in the last 5 years. • Over 85% of the population is food insecure (IPC, 2024).
Livestock	• Pasture loss from drought and invasive species. • Disease and fodder scarcity intensified by lack of vet services. • Beekeeping declines as flora disappears.	• Livestock herds have declined by up to 60% since 2015 in worst-hit communities. • Beekeeping—once supporting 30% of households—has collapsed. • Household wealth and resilience eroded.
Ecosystems & Land	• Soil erosion averages 15–20 tons/ha annually on uplands. • Deforestation for charcoal and fuelwood accelerates desertification. • Loss of perennial cover.	• 35% of tree and shrub cover lost in two decades. • 15% of terraced farmland destroyed by erosion and floods. • Siltation in Wadi Hattat reduces water availability and irrigation capacity.
Livelihoods & Economy	• Market collapse worsened by conflict, checkpoints, and climate shocks. • Traders exploit volatility, buying surpluses cheap in good years and selling high in bad years.	• Farmgate prices crash during surplus, leaving farmers in debt. • Distress sales of assets, migration, and child labor rise. • Women spend hours daily fetching water, increasing gender burdens.

6.1 Integrated Climate Vulnerability & Livelihoods Matrix – Shabwah & Abyan Target Districts

The targeted districts of Shabwah and Abyan face acute and interconnected climate vulnerabilities that threaten the very foundation of their rural economies. Agriculture, the primary livelihood, is under severe stress from recurrent droughts, increasingly destructive flash floods, salinity intrusion in coastal areas, and long-term land degradation. In districts like Bayhan, Nisab, and Markhah, cereals and sesame—a hallmark cash crop—suffer from crop failure rates exceeding 60–70% during drought years, while floods regularly wash away fragile irrigation networks and terraces. Livestock herds, once a reliable asset, have declined by 40–60% across many areas due to fodder scarcity, disease, and the collapse of grazing lands. Beekeeping, a traditional high-value activity in places like Nisab and Al-Mahfad, has been devastated by drought-induced floral loss and floods that destroy hives. These combined shocks erode food security, with districts like Sarar now reporting over 85% of the population as critically food insecure.

The coastal districts, particularly Rodhum and Ahwar, illustrate how fisheries—though critical for livelihoods and income diversification—are equally exposed. Cyclones like Chapala (2015) and Mekunu (2018), rising sea surface temperatures, and coastal flooding have damaged landing infrastructure, degraded marine ecosystems, and threatened tuna, mackerel, and cuttlefish stocks that anchor local economies. Ecosystem degradation compounds these vulnerabilities, with estimates of 15–20 tons of soil lost per hectare annually in upland areas and up to 35% loss of vegetation cover in Sarar, undermining natural buffers against climate extremes. Market systems remain fragile, with disrupted infrastructure, price collapses (e.g., Lowder tomatoes losing 80% of value in 2023), and conflict-driven monopolies leaving households with 20–30% income losses in bad years. Together, these factors create a multi-layered vulnerability where climate shocks accelerate poverty, force asset depletion, and push communities into unsustainable coping strategies—highlighting the urgent need for integrated adaptation investments in water management, flood protection, ecosystem restoration, and livelihood diversification. Table below summaries all integrated vulnerability of each district.

Table 59: Integrated Climate Vulnerability & Livelihoods Matrix – Shabwah & Abyan Target Districts

Livelihood Sector	Key Districts	Climate Threats	Estimated Impacts	Priority Adaptation Needs
Crops (Cereals & Cash)	Bayhan, Nisab, Markhah, Sarar, Lowder, Al-Mahfad	• Recurrent droughts (2010–2024 cycles). • Flash floods damaging wadis & terraces. • Water scarcity & broken irrigation.	• Up to 70% crop failure in drought years (sorghum, maize). • 20–40% yield losses in cereals & vegetables. • Sesame (Bayhan hallmark crop) & tomatoes (Lowder) face sharp market crashes.	• Drought-resistant seeds (sorghum, millet, sesame). • Flood protection structures & irrigation canal rehabilitation/construction. • Crop diversification & market support (e.g., tomato processing in Lowder).
Livestock & Fodder	Nisab, Sarar, Lowder, Al-Mahfad, Rodhum, Bayhan	• Drought-driven pasture loss. • Flood damage to grazing lands. • Fodder shortages & disease.	• 40–60% herd losses since 2015. • Sheep/goats dominant but declining. • Honey collapsed by 20–75% (Sidr in Nisab, Ba Kazim in Al-Mahfad).	• Restocking + veterinary services. • Fodder crop promotion. • Honey sector revival (replant sidr, floral recovery). • Diversified income (apiculture, small trade).
Fisheries & Marine	Rodhum, Ahwar	• Cyclones (Chapala 2015, Mekunu 2018). • Salinity intrusion & stronger storms. • Flood-borne siltation damaging coastal ecosystems.	• Ahwar: >5,000 acres farmland lost to floods; contributes ~30% of Abyan fish production. • Rodhum: Top fishery in Shabwah; official catch 42 tons (YR 102m), underreporting artisanal scale. • Tuna, mackerel, cuttlefish dominate but stocks under pressure.	• Coastal ecosystem restoration (mangroves, wetlands). • Climate-proof landing sites, cold storage, & processing. • Sustainable fisheries management & diversification.
Ecosystems & Land	Bayhan, Markhah, Sarar, Lowder,	• Desertification, soil erosion, and vegetation loss. • Flash floods stripping topsoil (15–20 tons/ha annually).	• Hundreds of hectares degraded annually. • 35% loss of tree/shrub cover in Sarar. • Groundwater decline >15m in Abyan aquifers.	• Land use management & watershed protection. • Flood protection infrastructure. • Rehabilitation/construction of irrigation canals, grey and wastewater, water harvesting systems.

	Nisab, All districts	• Degradation of wadis (e.g., Bayhan, Markhah). • Spread of Prosopis (mesquite/sesban) invades watersheds and affect the biodiversity		• Soil conservation & reforestation. • Mesquite recycling for livelihoods diversification

6.1 List of key priorities and interventions of agriculture, livelihoods and ecosystems in Shabwah and Abyan Governorates

Water and land use management is the cornerstone of building climate resilience in Shabwah and Abyan, where recurrent droughts, flash floods, and soil degradation undermine agricultural production and rural livelihoods. Enhancing irrigation efficiency, rehabilitating and expanding irrigation canals, introducing water-harvesting systems, and applying sustainable land-use practices are urgent priorities to secure food systems, reduce vulnerability, and restore degraded ecosystems. These measures are critical not only for sustaining crops and livestock but also for safeguarding household incomes in the face of intensifying climate variability.

The interventions are structured under two broad categories. Smart agriculture technologies and ecosystem-based adaptation practices include drip irrigation, mulching, low tunnels, and climate-resilient nurseries, all designed to reduce water losses, stabilize yields, and conserve soil fertility. Livelihood diversification through ecosystem-based approaches strengthens adaptive capacity through value chains for sesame, dates, lemons, and honey, alongside climate-resilient fodder farming to secure livestock feed and reduce grazing pressure. Together, these priorities provide an integrated pathway that links efficient water use, sustainable land management, and diversified income sources—key to building resilience and ensuring sustainable development in both governorates.

Table 60: List of Agriculture, Ecosystems and Livelihoods interventions

Category	District	Intervention (Technical Description)	Climate Rationale
Smart Agriculture Technologies & Ecosystem-based Adaptation Practices	All districts (Shabwah & Abyan)	**Drip Irrigation Systems:** Installation of modern drip irrigation networks for fruit trees, sesame, vegetables, and fodder plots including filtration units, low-pressure pipes, and emitters to deliver precise amounts of water directly to plant roots. (Output 2.4)	Reduces water losses by 40–50%, improves water productivity under severe scarcity, and lowers dependence on over-abstracted aquifers. Enables farmers to sustain yields despite declining rainfall and high evaporation rates.
	Rudhom, Ahwar, Markha, Bayhan	**Low Covered Tunnels:** Construction of plastic-covered tunnels for vegetable and fodder cultivation to protect crops from high temperatures, erratic rainfall, and pests. (Output 2.4)	Extends the growing season, reduces heat and flood damage, and stabilizes vegetable supply. Increases yields by 20–30% compared to open-field farming in drought-prone and saline-affected areas.
	Rudhom, Ahwar, Markha, Bayhan	**Mulching and Soil Covering:** Application of organic and plastic mulches on farmlands to conserve soil moisture, suppress weeds, and reduce surface evaporation. (Output 2.4)	Cuts evaporation losses by up to 25%, maintains soil fertility, and protects against salinity build-up in coastal zones. Strengthens resilience of smallholders facing recurrent droughts.

	Sarar, Al-Mahfed, Nisab	**Village Greenhouses and Nurseries:** Establishment of climate-resilient greenhouses and community nurseries to produce adaptive seedlings (vegetables, lemons, coffee, agroforestry species). (Output 2.4)	Provides continuous seedling supply of drought- and salinity-tolerant crops, reduces replanting costs, and supports reforestation. Ensures climate-resilient planting materials for household farms and EbA initiatives.
Improved Livelihood Diversification through EbA Approaches	Lawder, Bayhan, Ahwar	**Sesame Value Chain Development:** Rehabilitation of degraded lands for sesame cultivation, reforestation of traditional growing areas, and establishment of oil-extraction and packaging units. (Output 2.5)	Sesame is drought-tolerant and grows well in semi-arid soils. Restoring the value chain creates income resilience, supports women farmers, and rehabilitates ecosystems degraded by overgrazing.
	Bayhan, Rudhom	**Date Palm Value Chain:** Restoration of date palm groves with improved irrigation; introduction of post-harvest handling, cold storage, and packaging facilities for local and export markets. (Output 2.5)	Dates are highly salt- and drought-tolerant. Reviving palm groves in coastal and semi-arid areas sustains income in saline-affected soils and enhances household food security.
	Sarar, Al-Mahfed	**Climate-Resilient Lemon Expansion:** Planting of drought-resistant lemon varieties with drip irrigation and establishment of market linkages for value addition (packing, drying, juice processing). (Output 2.5)	Lemon is a climate-resilient crop suited to semi-arid highlands. Scaling up cultivation diversifies household income and strengthens adaptive farming under reduced rainfall.
	Bayhan, Nisab	**Honey Production Scaling (Sidr Restoration):** Reforestation of Sidr trees combined with modern	Sidr honey is globally valued; restoration of trees enhances pollination services, biodiversity, and market income. Reduces vulnerability of rural households to drought-driven crop failure.

		beekeeping and honey processing facilities, including bottling and quality testing. (Output 2.5)	
	Lawder, Al-Mahfed, Rudhom, Nisab	**Fodder Farming Expansion:** Establishment of climate-resilient fodder crops (sorghum, alfalfa, drought-tolerant grasses) using improved irrigation and soil conservation techniques. (Output 2.5)	Reduces grazing pressure on fragile rangelands, secures livestock feed during droughts, and decreases livestock mortality by 15–20%. Provides an alternative income source while restoring degraded land.
	Rudhom & Ahwar	**Mesquite (Prosopis juliflora) Recycling and Land Rehabilitation:** Removal and controlled harvesting of invasive mesquite stands, with recycling into charcoal, briquettes, furniture, and fodder supplements. Parallel reforestation with native, drought-resilient species (e.g., Sidr, acacia) to restore ecological balance. (Output 2.5)	Mesquite (Prosopis juliflora) Recycling and Land Rehabilitation: Removal and controlled harvesting of invasive mesquite stands, with recycling into charcoal, briquettes, furniture, and fodder supplements. Parallel reforestation with native, drought-resilient species (e.g., Sidr, acacia) to restore ecological balance. (Output 2.5)

Energy for Climate Resilient Practices

CHAPTER 5

Energy for Climate Resilient Practices

6.1 Electricity Sector Profile

The nexus of conflict, climate change, economic instability, and institutional fragmentation in Yemen has resulted in a prolonged multidimensional crisis, with particularly severe repercussions for the energy sector. Over a decade of armed conflict has systematically undermined the country's fragile power infrastructure. The destruction of power plants, transmission systems, and distribution networks has left substantial segments of the population without reliable electricity. According to the World Bank's 2023 household survey, only 15 percent of Yemeni households rely on the public grid as their primary source of lighting, with disparities in access sharply accentuated between urban and rural communities[1].

This chapter presents an overview of Yemen's energy landscape and the emerging but fragmented renewable energy market, and the profound climatic pressures shaping future energy demands. It then presents a portfolio of context-specific, scalable interventions designed to strengthen climate resilience, improve essential services, and support economic recovery through decentralized renewable energy solutions.

These interventions have been rigorously prioritized using a Multi-Criteria Analysis (MCA) framework, evaluating each against climate adaptation benefits, technical feasibility, social inclusivity, multi-sectoral integration, and potential for replication. Grounded in field assessments and stakeholder consultations, the proposed projects are tailored to the diverse needs of Yemen's urban, peri-urban, and rural communities, ensuring alignment with both local priorities and global environmental goals.

6.1 Electricity Generation

Yemen's power sector has historically been dominated by fossil fuels, primarily diesel and heavy fuel oil (HFO). Dependence on imported refined products, coupled with limited domestic refining capacity and constrained foreign exchange, has left the electricity system highly vulnerable to global price volatility, supply-chain disruptions, and recurrent fuel shortages. By 2014, installed generation capacity reached approximately 1.5 GW[2]. However, due to aging infrastructure, insufficient maintenance, and operational constraints, the reliably available capacity was significantly lower, at around 1 GW. The electricity generation system was organized into three main components[2].

- **National Grid Power Plants:** These plants connected 13 major cities through a 132 kV transmission network, forming the backbone of Yemen's centralized electricity supply.
- **Isolated Grid Systems:** Independent networks operated in Hadhramout, specifically in the coastal zones and Al-Wadi regions, serving local loads outside the national grid.
- Decentralized Generation: Small diesel generators were distributed across some secondary cities and rural areas, providing critical supply where grid access was limited.

The war has systematically destroyed critical infrastructure, including power plants, transmission lines, and distribution networks, leading to severe reductions in electricity access across all sectors. Despite this, electricity generation remains overwhelmingly dependent on fossil fuels. In 2022, oil accounted for nearly 78% of total generation, while natural gas contributed only 2.5%[3]. The remainder of the electricity supply is largely derived from renewable sources, primarily solar photovoltaic systems[3].

The country relies almost entirely on imported refined petroleum, spending approximately US$1.2 billion annually to generate just 1 GW of electricity[4], which meets only 22% of the estimated maximum national demand of 4.7 GW in 2025[5]. This extreme dependence exposes the sector to price volatility, supply disruptions, and foreign exchange constraints. Furthermore, diesel prices have surged 300–500% since 2015, making fuel-based electricity prohibitively expensive for most households and businesses, and underscoring the urgent need for alternative and decentralized energy solutions[3].

6.1 Status of Electrification Rates and Conflict Impacts

Prior to the escalation of conflict in 2015, Yemen's electrification rate reflected significant developmental challenges and stark disparities between urban and rural areas. According to World Bank estimates, approximately 40% of Yemen's population had access to electricity by 2014, leaving roughly 60% of the population without reliable electricity supply[6].

This national average concealed profound inequalities in electricity access between different regions and communities. In urban centers, access reached approximately 85%[6], though even connected households faced frequent and prolonged outages lasting 12–20 hours daily due to generation shortages and grid instability. In contrast, rural electrification rates remained critically low at approximately 23%, with many remote communities entirely excluded from grid connectivity. These disparities were indicative of the broader urban-rural divide, where up to 75% of Yemen's population resided in rural areas.

The protracted conflict has since precipitated a catastrophic deterioration in energy access. By 2023, only 15% of households relied on the public electricity network as their primary source of lighting[1]. Geographic disparities remain stark: urban households exhibit a grid connection rate of 26%, semi-urban households 15%, and rural communities a critically low 7%[1]. In response, households increasingly rely on solar PV reaching up to 81% in certain areas, and electricity from private networks, which provides power for lighting 17% of households, depending on location[1]. These patterns underscore the compounded effects of conflict, infrastructure damage, and socioeconomic vulnerability, highlighting the urgent need for targeted interventions to restore and expand electricity access across the country.

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Persistent electricity shortages have severely impeded the operation of essential public services and economic sectors, including water supply and sanitation, healthcare, industrial activity, food storage, transportation, and education, disproportionately affecting vulnerable populations. Limited access to reliable electricity has constrained industrial productivity, agricultural modernization, and the effective functioning of healthcare and educational facilities, compounding Yemen’s pre-existing developmental challenges even before the onset of conflict. As shown in Table 61, per capita electricity consumption has fallen dramatically during the conflict, decreasing from approximately 217 kWh in 2014 to around 58 kWh

per person annually by 2020[7]. This decline is stark when compared to the MENA regional average, which exceeds 2,000 kWh[8]. Such extremely low consumption reflects both supply collapse and widespread poverty. The electricity deficit critically undermines essential services, including hospitals, schools, water pumping, and local economic activities. The table below summarizes Yemen's electricity access indicators during this decade.

Table 61 Yemen Electricity Access Indicators (Pre and after-Conflict)

Indicator	National Average	Urban Areas	Rural Areas	Year
Grid Connection Rate	40	83	23	2014[6]
Grid Connection Rate	83.6	75.3	75.3	2023[9]
The population relies on public electricity (%)	15	26	7	2023[1]
Electric power consumption (kWh per capita)	54	N/A	N/A	2022[7]
Electricity production from oil sources (% of total)	77.8	N/A		2023[9]
Solar PV as Main Source of Electricity	70	59	79	2023[1]

6.1 Topographic and Climatic Constraints on Grid Electrification

Yemen's rugged geography and harsh climate present fundamental barriers to energy access and resilience. The nation's terrain is characterized by mountainous regions, isolated valleys, and dispersed rural settlements, making the extension of a centralized grid technically complex and economically prohibitive[10]. These challenges are intensified by climatic stressors, including rising temperatures, droughts, and extreme weather, which further threaten rural livelihoods and essential services. With 70% of Yemen's population lives in rural areas, a significant portion of which are situated in these remote and fragmented regions[10]. The spatial dispersion of households across vast and difficult terrain creates severe logistical and economic constraints for national electrification strategies.

Recognizing these realities, the Yemeni government has categorized rural populations into four groups based on their proximity to and feasibility of connection with the national grid[11]:

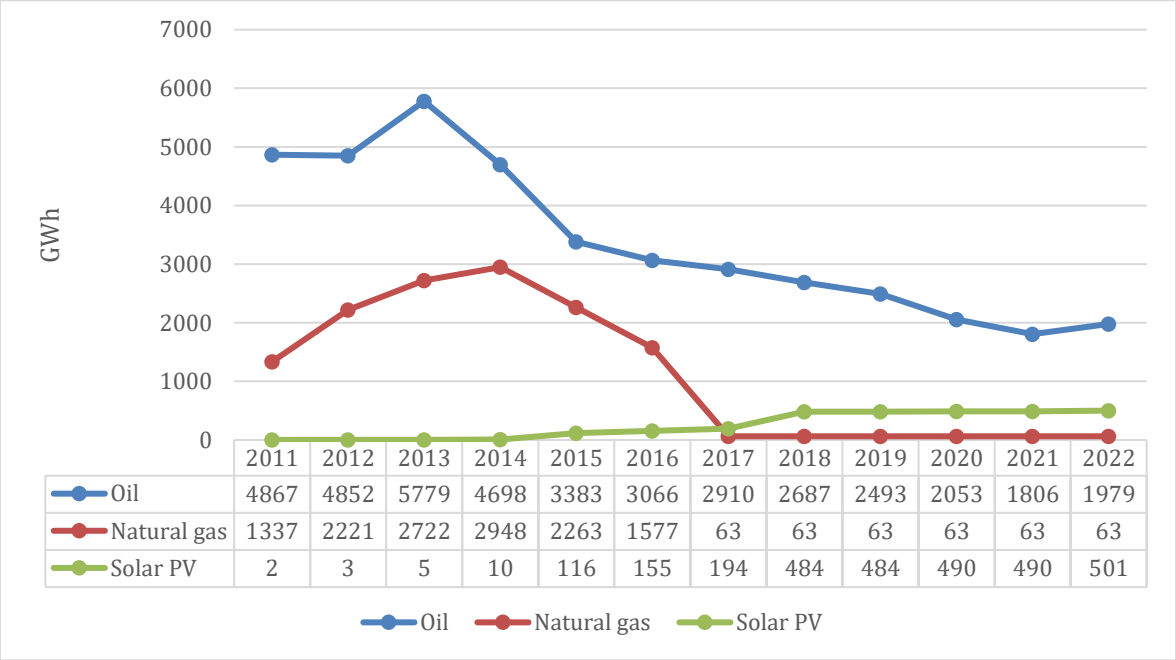
- Type One: Grid-Proximate Communities: Villages near existing grid infrastructure, where connection is financially and technically viable.
- Type Two: Moderately Remote Populations: Clustered villages farther from the grid, where connection is feasible but at a marginally higher cost.
- Type Three: Difficult-to-Connect Populations: Clustered villages near the grid but located in highly rugged terrain, making extension prohibitively expensive or technically unviable.
- Type Four: Isolated Mountainous Populations: Highly scattered households in remote mountainous regions, for which grid connection is entirely impractical.

Critically, an estimated 38% of Yemen's rural population falls into Type Three and Four categories, for whom the national grid is not a feasible solution[6]. These geographic and climatic conditions underscore the critical importance of decentralized renewable energy systems. Such systems can be tailored to local constraints, bypassing the need for extensive grid infrastructure. By aligning technology with geographic

and climatic realities, decentralized renewable energy not only provides sustainable access but also enhances community resilience, contributing directly to climate change adaptation and mitigation goals.

6.1 Renewable Integration in Generation Mix

Error! Reference source not found., summarizes Yemen's electricity generation by source over the period 2012–2022, based on data from the International Energy Agency (IEA). For most of this decade, the electricity sector was predominantly dependent on oil and natural gas; however, generation from both fuels experienced pronounced declines. Oil-based generation decreased by more than 60%, falling from 4,852 GWh in 2012 to 1,979 GWh in 2022, while natural gas output contracted by nearly 97%, dropping from 2,221 GWh in 2012 to only 63 GWh after 2017[12].



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Oil	4867	4852	5779	4698	3383	3066	2910	2687	2493	2053	1806	1979
Natural gas	1337	2221	2722	2948	2263	1577	63	63	63	63	63	63
Solar PV	2	3	5	10	116	155	194	484	484	490	490	501

Figure 57: Yemen's electricity generation by source over the period 2012–2022:

In *Yemen Mixed-Renewable Energy Investment Plan*[5] developed by UNDP, a crucial framework designed to address the nation's severe electricity crisis while advancing its climate resilience and decarbonization objectives. As shown in **Error! Reference source not found.**, this plan models three pathways for power sector expansion through 2050, each with varying levels of renewable energy integration and decarbonization objectives[5]:

- **Scenario A (Minimal Effort):** This is the least ambitious plan. It focuses on replacing old steam, diesel, and gas power plants with more efficient natural gas Combined Cycle plants. Solar PV and wind energy are introduced slowly starting in 2025.
- **Scenario B (Determined Effort):** A more ambitious plan aiming for a 25-34% renewable energy share by 2050. It involves a higher use of solar, wind, and geothermal energy, while still phasing out old plants in favor of CC technology.

- **Scenario C (Aggressive Effort):** The most ambitious plan, targeting a 35-50% renewable energy share by 2050. It requires a rapid expansion of solar, wind, and geothermal power, especially after 2025. This scenario significantly reduces dependency on imported natural gas and CC plants.

Table 62: Summary of UNDP Yemen's Energy Generation Scenarios (2021-2050)

Scenario	Ambition Level	Key Actions	RE Target by 2050	Role of Natural Gas
A	Minimal Effort	Replaces old power plants with efficient Combined Cycle (CC) plants. Slowly introduces solar and wind starting in 2025.	Not specified (Low)	High Dependency. Primary strategy is switching to efficient gas (CC).
B	Determined Effort	Higher and earlier penetration of solar, wind, and geothermal. Continues to replace old capacities with CC.	25% - 34%	Moderate Dependency. Still relies on CC plants but with significant RE growth.
C	Aggressive Effort	Rapid and massive expansion of solar, wind, and geothermal, especially after 2025.	35% - 50%	Low Dependency. Explicitly aims to minimize imports and reliance on natural gas.

As shown in **Error! Reference source not found.**, The UNDP model outputs for 2035 highlight how the scale of renewable energy deployment will shape long-term energy security, costs, and emissions. While greater shares of renewables reduce fuel import dependence and environmental impacts, they also demand higher upfront investments, infrastructure upgrades, and strong coordination with private partners. Across all modeled scenarios, however, natural gas continues to play a major role of the power system in all scenarios.

Under the Minimal Effort pathway, total installed capacity is projected at approximately 8.94 GW by 2035. Aging generation units are replaced with high-efficiency combined-cycle gas plants, while solar PV and wind are introduced at moderate levels of roughly 1,005 MW each, corresponding to 11.2% of total capacity. Gas-fired generation accounts for approximately 5,901 MW (66.0%), whereas diesel and steam plants collectively provide around 1,027 MW (11.5%). This pathway achieves near-term efficiency gains and modest renewable integration but maintains a high dependency on gas.

The Determined Effort pathway, envisions a total system capacity of approximately 9.16 GW, including 1,189 MW of PV (13.0%), 1,189 MW of wind (13.0%), 5,301 MW of combined gas (57.9%), and incremental geothermal and biomass generation. This scenario accelerates the integration of renewable energy while maintaining substantial gas capacity to ensure system reliability, balancing decarbonization objectives with technical and financial feasibility.

In the 2035 Aggressive Effort pathway, projects a total installed capacity of approximately 9.67 GW. This includes 1,655 MW of PV (17.1%), 1,655 MW of wind (17.1%), 4,743.5 MW of combined gas (49.1%), and expanded geothermal capacity. Despite the highest renewable penetration among all scenarios, nearly half of the capacity remains gas-based, highlighting the continued need for dispatchable resources to

maintain system stability and reliability during the energy transition.

Table 63:UNDP-Yemen's Projected Energy Capacity in 2035 (GW).

Technology	Scenario A (Minimal Effort)	Scenario B (Determined Effort)	Scenario C (Aggressive Effort)
Combined Cycle (CC)	5.32	4.69	4.17
Solar (PV)	1.00	1.19	1.65
Wind	1.00	1.19	1.65
Geothermal (Geo)	0.00	0.42	0.59
Biomass (Bio)	0.00	0.03	0.00
Gas	0.58	0.61	0.58
Diesel	0.55	0.55	0.55
Steam	0.48	0.48	0.48

6.1 Public Grid Challenges

Yemen's centralized electricity grid is characterized by severe fragility, resulting from years of conflict, underinvestment, and systemic operational deficiencies. Technical shortcomings, such as aging infrastructure, lengthy transmission and distribution grids, and poor voltage regulation, combine with non-technical challenges, including electricity theft and faulty metering, to create high energy losses and unreliable supply. These challenges are further exacerbated by escalating demand pressures, driven by population displacement, urban expansion, and rising temperatures that increase the need for cooling in vital services.

The following Table 64, summarizes the key challenges and their implications for energy planning and potential interventions:

Table 64. Public Grid Key Challenges and Implications for Energy Planning

Category	Specific Challenges	Implications for Energy Planning & Project Design
Technical Issues	Generation capacity inadequacy; aging infrastructure; voltage regulation issues; phase imbalance; dependence on diesel/HFO.	Limits feasibility of grid-connected solutions; reinforces need for decentralized renewable energy (DRE) and energy efficiency (EE) investments.

Non-Technical Issues	Electricity theft; metering discrepancies; unmetered public supply; consumer behavior.	Increases financial losses; reduces utility revenue and limits reinvestment capacity; necessitates community engagement and modernized metering.
Planning & Financial	Limited strategic planning; insufficient maintenance; financial constraints.	Hinders grid recovery and expansion; underscores importance of near-term off-grid solutions and DRE-based mini-grids for critical services.

6.1 Overview of the Decentralized Renewable Energy (DRE) Sector

5..1 Solar resource Potential

Yemen possesses exceptional solar energy resources, characterized by high irradiation levels and substantial annual sunshine hours. As shown in Figure 58, the country receives an average of 5.2 to 6.8 kWh/m² per day of solar insolation, translating to an annual average of approximately 1,800 to 2,200 kWh/m². This places country among the world's most suitable regions for solar energy development[10].

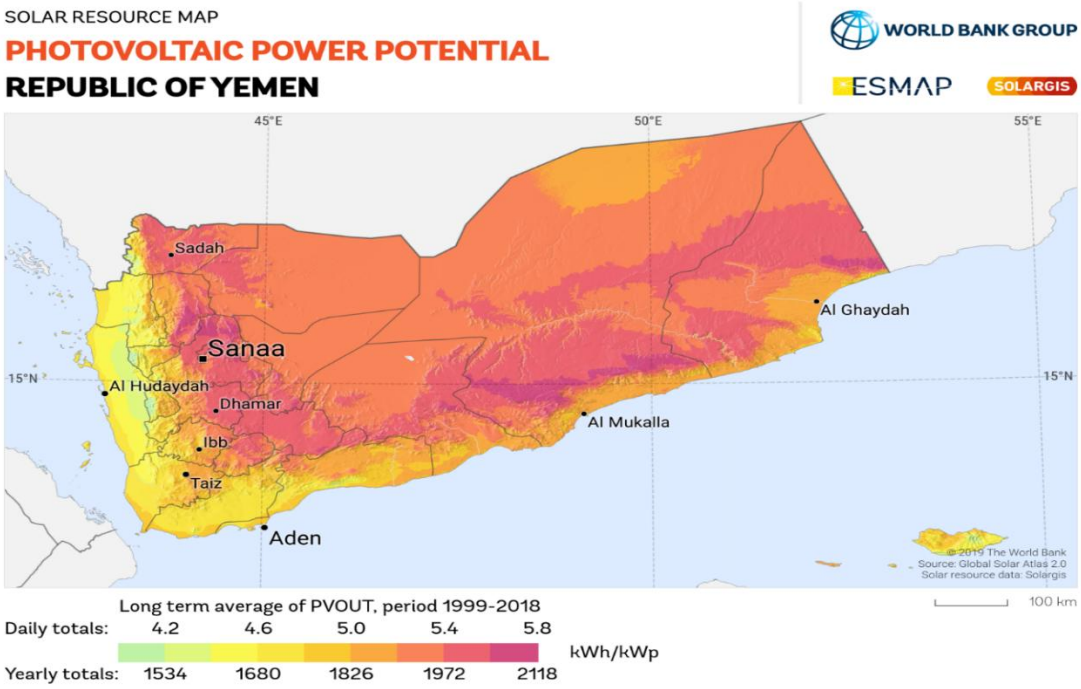


Figure 58. Photovoltaic power potential, Yemen.

The geographical distribution of solar resources varies across Yemen's diverse topography, average daily sunshine hours range from 7.3 hours in the northern highlands to over 9.1 hours on Socotra Island. For instance, Sana'a, enjoys an average of 7.7 hours of sunshine daily, which remains high at approximately 8.2 hours even during the winter months[13]. In terms of irradiation, the central-western governorates of Al Bayda and Dhamar record the highest levels at around 6.8 kWh/m²/day. Regions including Amran, Sana'a, Ibb,

Al-Dhalee, and Marib receive between 6.6–6.7 kWh/m²/day, while areas like Hajjah, Al Mahwit, Al Hudaydah, and Al Mahrah have slightly lower, yet still high, levels of 5.4–5.8 kWh/m²/day[13].

This abundant resource translates into a substantial technical potential. Studies estimate Yemen's total solar capacity could reach approximately 17 GW for large-scale Concentrated Solar Power (CSP) plants and 2.2 GW for solar PV systems[10]. The convergence of high solar potential and a critical need for reliable electricity has positioned solar energy as a cornerstone of Yemen's decentralized energy response.

5..2 Market Evolution and Current Penetration

The growth of Yemen's solar market is a direct consequence of the near-total collapse of its centralized energy infrastructure, exacerbated by the conflict that escalated in 2015[14]. The national grid, fragile even before the war, became unable to provide reliable electricity, leading to a humanitarian energy crisis [10]. Initially, the population turned to diesel generators; however, severe fuel shortages and soaring costs rendered this option increasingly impractical[14]. This vacuum catalyzed a spontaneous, grassroots transition toward decentralized solar energy, a phenomenon often termed "Yemen's solar revolution"[14]. The development of Yemen's solar market can be analyzed in three distinct phases, each shaped by the country's deteriorating security and energy landscape.

- **Niche Market (Pre-2014):** Before the conflict, solar PV was a niche technology confined to small, donor-funded projects, telecommunications infrastructure, and a few affluent households. Its contribution to the national energy mix was insignificant. IEA data from 2012 shows solar PV generated only 3 GWh, compared to over 7,000 GWh from fossil fuels[12]. High costs and the dominance of subsidized diesel generators kept solar on the periphery[14].
- **Conflict-Driven Emergency Growth (2014–2020)**: The collapse of the public electricity grid after 2014 precipitated a rapid and disorderly expansion of Yemen's solar market[15]. With no reliable public electricity, solar PV became the default solution for basic energy needs[15]. A market assessment commissioned by the World Bank in 2016 estimated that the market penetration of solar power for lighting and appliances reached as high as 75% among households in selected urban areas, and approximately 50% in broader urban settings[16].
- This period was characterized by emergency procurement, with households and businesses bought whatever systems were available through informal channels[15]. This unregulated expansion created a market flooded with low-quality and counterfeit products, particularly PV modules and batteries. The lack of quality control and technical expertise led to high system failure rates. Experts estimated that 70% of PV-system components during this period were either counterfeit or of substandard quality, with modules and batteries accounting for failures[10].
- The prevalence of low-quality equipment, combined with limited local technical expertise and inadequate after-sales service, undermined system reliability, shortened lifespans, and increased long-term costs for end users.
- **Market Consolidation and Sophistication (Post-2020):** A shift toward technological maturity and market consolidation. The market has seen a growing availability of higher-quality equipment, the establishment of more reliable supply chains, and the emergence of specialized solar enterprises. This phase is marked by the increasing application of larger PV systems (>100 kW) in the agricultural,

commercial, and industrial sectors[10]. A World Bank household survey conducted in 2023 revealed that 59% of households in urban districts rely on solar PV systems as their main source for basic lighting, compared to 79% in rural areas[1].

5..3 Challenges to Renewable Energy Deployment

Yemen's renewable energy sector faces a unique set of interlinked challenges, shaped by years of conflict, a fragile institutional framework, market limitations, and the ongoing humanitarian crisis. These factors affect infrastructure, technical capacity, regulatory clarity, financing, and the quality and sustainability of deployed systems. Understanding these constraints is essential for designing interventions that are both feasible and impactful. As summarized in Table 65.

- **Infrastructure and Technical Capacity**

Years of conflict have devastated Yemen's energy infrastructure, leaving generation, transmission, and distribution networks severely damaged. The absence of a functioning national grid has created a vacuum partially filled by decentralized solar solutions. However, the lack of a robust grid poses challenges for the large-scale deployment of renewables, particularly for mini-grid and utility-scale projects requiring reliable network support.

Technical capacity is also limited. While informal solar technicians have emerged, there is a shortage of formally trained professionals. This gap contributes to inconsistent system quality, reduced efficiency, and shortened lifespan of installed systems. Capacity-building measures are therefore essential to ensure sustainability.

- **Institutional and Regulatory Barriers**

The renewable energy sector in Yemen suffers from weak and fragmented institutional frameworks. As of 2024, there is no comprehensive national renewable energy strategy or enforced technical standards, creating uncertainty for investors and allowing low-quality and counterfeit equipment to enter the market. Regulatory gaps further hinder growth. Mini-grid and decentralized energy regulations are unclear, import tariffs for solar components are inconsistent, and limited government budgets constrain policy enforcement. The reduction in staffing within relevant ministries, significantly exacerbates these challenges. This situation has resulted in a diminished institutional capacity to effectively support the development of the sector.

- **Financial Constraints**

Financing remains a major barrier to renewable energy deployment. Households and small businesses often cannot access affordable credit, and banks are reluctant to lend due to high risk and insufficient collateral. Public institutions such as schools and health facilities face limited or nonexistent budget allocations for energy investments. Although donor-funded pilot projects have demonstrated technical feasibility, they often lack sustainable financing mechanisms for scale-up. Upfront payment models remain the norm, excluding most potential beneficiaries from adopting renewable energy solutions.

- **Humanitarian Crisis and Increasing Demand**

The ongoing humanitarian crisis both drives and constrains renewable energy adoption. Destruction of conventional infrastructure and high diesel costs make solar power essential for coping yet rising urban populations and displaced communities intensify energy demand. Climate change further exacerbates the

situation, increasing cooling needs in essential service facilities such as schools and hospitals. While this underscores the need for renewable solutions, household income constraints make energy highly price-sensitive, creating a persistent supply-demand mismatch.

- **Quality Challenges and Market Failures**

The rapid, unregulated growth of Yemen's solar market has created serious quality and market issues. Substandard equipment fails prematurely, while counterfeit products with fake certifications erode consumer trust. Lack of local testing or certification facilities means quality verification often requires costly international shipments, placing safeguards out of reach for most consumers. Additionally, absence of standardization leads to system incompatibilities and technological lock-in, forcing users to replace entire systems when individual components fail. These challenges undermine the sustainability and credibility of solar interventions, emphasizing the need for strict quality control, standardized components, and capacity-building within the supply chain.

- **Supply Chain and Logistics Limitations**

Damaged transport infrastructure, including roads and ports, hampers delivery of solar equipment especially to remote areas. Security incidents further increase costs and the risk of equipment loss, particularly for rural and hard-to-reach districts.

- **Community Awareness and Acceptance**

Limited knowledge about solar technology and its benefits can result in low adoption or misuse. Cultural and social norms may restrict participation in productive use programs, especially for women, affecting equitable access and the sustainability of interventions.

- **Operation & Maintenance (O&M) Sustainability**

Few local enterprises or technicians possess the capacity to provide long-term O&M for mini-grids or larger systems. The lack of spare parts, particularly in rural districts, risks system downtime or abandonment, undermining project impact.

- **Environmental and Climate Risks**

High temperatures, dust, sandstorms, and seasonal flooding can degrade solar panel efficiency and battery lifespan. Extreme weather events, including flash floods and cyclones, pose direct risks to infrastructure.

- **Policy and Incentive Gaps**

The absence of government incentives, feed-in tariffs, or subsidies for renewable energy slows adoption. Furthermore, unclear frameworks for private sector participation in mini-grids and public-private partnerships constrain investments on a scale.

- **Monitoring, Reporting, and Evaluation (M&E) Challenges**

Limited local capacity for monitoring and evaluation hampers the ability to track system performance, energy usage, and social impact. This constrains evidence-based decision-making and the replication of successful interventions.

Table 65. Challenges to Renewable Energy Deployment

Challenge	Description	Implications for Project Design & Implementation

Infrastructure & Technical Capacity	Damaged grid; limited technical expertise; reliance on informal technicians	Focus on off-grid and mini-grid solutions; include capacity building and technical training programs; design resilient systems for low-maintenance operation.
Institutional & Regulatory Barriers	Weak, fragmented institutions; lack of renewable energy policy; unclear mini-grid regulations	Engage with local authorities for policy clarity; design interventions aligned with existing institutional structures; include regulatory capacity strengthening.
Financial Constraints	Limited access to credit for households; constrained budgets for schools/health facilities; high cost of quality solar	Develop blended financing approaches; donor co-financing; provide targeted subsidies or pay-as-you-go models; prioritize cost-effective technologies.
Humanitarian & Demand Pressures	Population displacement; high energy needs in schools and hospitals; climate-induced extreme weather	Prioritize interventions in high-demand areas; integrate climate-resilient technologies; focus on essential services; plan for flexible scaling.
Quality Challenges & Market Failures	Substandard/counterfeit equipment; lack of standardization; technological lock-in	Procure verified equipment; build local testing and QA capacity; standardize components to ensure interoperability and maintainability.
Security & Access Constraints	Conflict zones; restricted access; operational risks	Implement security risk assessments; adapt logistics and scheduling; engage local communities for support and monitoring.
Supply Chain & Logistics Limitations	Damaged roads, customs delays, transport insecurity	Plan for buffer stocks; local sourcing where feasible; flexible delivery schedules; strengthen local supply chains.
Community Awareness & Acceptance	Limited knowledge on solar tech; social/cultural barriers	Conduct awareness campaigns; gender-sensitive and inclusive training; engage community leaders to promote acceptance.
Operation & Maintenance Sustainability	Lack of local O&M capacity; limited spare parts	Train local technicians; establish maintenance plans; ensure availability of spare parts and monitoring systems.
Environmental & Climate Risks	High temperatures, dust, flooding, extreme weather	Select climate-resilient equipment; design protective infrastructure; integrate preventive maintenance practices.
Policy & Incentive Gaps	No feed-in tariffs, subsidies, or incentives for DRE	Design financially viable and self-sustaining business models.
Monitoring, Reporting & Evaluation	Limited local capacity to track performance and impact	Include M&E framework; train local staff; integrate digital monitoring where feasible.

6.1 Impacts of Climate Change and Electricity Challenges on the Learning Environment

The findings of this section draw on both comprehensive desk reviews and field visits to selected schools and community sites across the target governorates. These field observations confirmed that educational facilities are increasingly affected by the compounded impacts of climate change manifested through prolonged heatwaves, rising ambient temperatures, recurrent dust and sandstorms, coastal humidity and salinity intrusion, erratic rainfall, and flash flooding events. On-site temperature measurements and interviews confirmed that classroom temperatures frequently exceeded 40°C during peak summer months, particularly in coastal and lowland schools with limited ventilation, non-insulated roofs, and an absence of passive cooling or green design features. Furthermore, limited access to safe drinking water and unreliable electricity were found to significantly compromise health conditions and the overall learning environment, especially during the hottest months.

Field evidence also demonstrated that while some schools have adopted solar photovoltaic PV systems, less than 10% of institutions nationwide operate functional systems[17]. The majority of installed systems were found undersized, poorly maintained, or technically obsolete, rendering them unable to sustain essential services such as lighting, cooling, computer laboratories, administrative operations, or water pumping. In the surveyed areas, the need for reliable energy and climate-resilient interventions remains acute, affecting approximately 78% of schools in Al-Mukalla, 74% in Aden, and 90% in the southern districts of Al-Hodeidah. These findings underscore the urgency of deploying technically robust and context-appropriate solar PV solutions as part of an integrated adaptation strategy.

Furthermore, field consultations confirmed that school and community infrastructure are interdependent. A key vulnerability is the lack of reliable electricity for nearby drinking water systems. Integrating solar power to support these facilities would ensure sustainable water access and improve hygiene, significantly boosting the project's climate resilience. Moreover, the growing interest among school leadership and local suppliers signals strong potential for scaling up these interventions, fostering a sustainable, low-carbon, and climate-resilient educational environment across Yemen’s most climate-vulnerable regions.



5..1 Education Sector Overview

Yemen's education system is organized into three main levels, Basic Education, Secondary Education, and Tertiary Education, and is jointly administered by several national authorities. As shown **Error! Reference source not found.**, the Ministry of Education (MoE) oversees pre-basic, basic, and general secondary education, while the Ministry of Technical Education and Vocational Training (MoTEVT) is responsible for vocational and post-basic training programs. The Ministry of Higher Education and Scientific Research (MoHESR) manages universities and other tertiary institutions, regulating both public and private higher education[18].

The formal education structure comprises nine years of Basic Education, which is compulsory and serves as the foundation of Yemen's education system, followed by three years of Secondary Education, designed to prepare students for higher education or vocational training. Access to early childhood education remains limited, particularly in rural and conflict-affected areas. Specifically, the MoE administers the following levels[19]:

- Kindergarten: Pre-primary education for children aged three to six. Access to early childhood learning facilities is limited. While this phase not mandatory, its importance is increasingly recognized.
- Basic Education: Grades 1–9, starting at age six. According to the 1992 General Law on Education, basic education is free, compulsory, and accessible to all children without discrimination.
- Secondary Education: Grades 10–12, lasting three years after basic education, providing preparation for tertiary studies or vocational pathways.

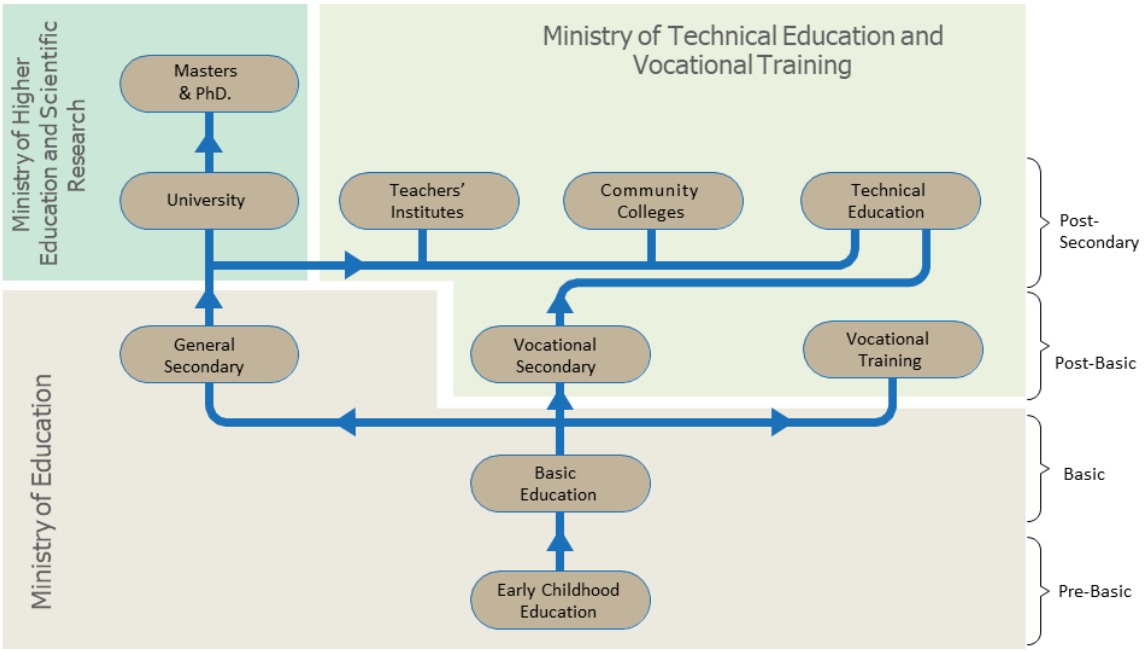


Figure 59 the structure of Yemen's education system

The sector has been severely strained by the protracted conflict. According to UNICIEF, more than 4.5 million children are estimated to be out of school, and over 3,700 schools are damaged, destroyed, or used for non-educational purposes such as displacement shelters[19]. Net enrolment rates have declined to around 33.9 percent in secondary education[20].

The combination of armed conflict, economic instability, and environmental stressors has further eroded the education system's capacity and resilience. Many schools function without reliable electricity, with water and sanitation systems damaged or non-operational, undermining both learning outcomes and health conditions[21]. These compounding challenges threaten the education sector's ability to support human capital recovery and climate adaptation. Strengthening institutional coordination and prioritizing renewable energy integration, teacher capacity development, and climate-resilient school infrastructure are essential steps toward restoring an equitable and sustainable education system in Yemen.

5..2 Education Infrastructure

As 2025, the Ministry of Education reported that 892 public schools across Hadramout[21]. As shown in Table 66, Mukalla hosts a total of 73 public governmental schools. These institutions are categorized into 51 primary schools, 10 secondary schools, and 12 schools offering both primary and secondary education[22]. Meanwhile, the Al Mukalla Rural district contains 24 schools, with 21 primary schools and 3 schools providing both educational levels. This distribution reflects the regional allocation of public educational resources[21,22]. Aden comprises 135 schools, including 95 primary schools, 25 secondary schools, and 16 combined primary and secondary schools[21,22].

Table 66 District-Level Breakdown of Public Government Schools targeted governorates (2025)

District	Primary	Secondary	Primary and Secondary	Total
Hadramout (Al Mukalla City)	51	10	12	73
Hadramout (Al Mukalla Rural)	21	0	3	24
Aden	94	25	16	135

Besides, in Al-Hodeidah the term "school" encompasses a diverse array of educational spaces, many of which do not meet the minimum standards for physical infrastructure. Field reports and humanitarian assessments consistently indicate that:

- A notable proportion of schools operate in temporary tents, typically provided by emergency education actors. These facilities are highly vulnerable to extreme weather conditions and offer limited protection, comfort, or educational quality.
- In displacement-affected areas, private homes are frequently repurposed as makeshift classrooms, often lacking basic teaching materials such as blackboards, seating, and reliable access to electricity.
- Open-air learning spaces, including areas under trees, within courtyards, or beneath temporary canopies, remain common, particularly in remote or conflict-affected zones where school buildings have been destroyed or rendered inaccessible.
- Many of the functional schools in these districts are non-permanent, partially damaged, or operating with incomplete structures, and the majority lack access to safe water, sanitation, and electricity (WASH+E) services.



Temporary Classes Build by Community Initiative - Al-Hodeidah - Hais

According to the World Bank report (2023)[17], the total number of schools in Yemen is approximately 17,000, based on 2011 records[17]. As depicted in Table 67, the total student enrollment in public governmental schools across Al Mukalla reached 62,797 in 2025. This total comprises 50,883 primary students and 11,914 secondary students. In contrast, the Aden district had a significantly larger enrollment of 154,333 students, encompassing 124,808 primary students and 29,525 secondary students. A more detailed breakdown shows that the Al Mukalla Rural district accounts for 2,697 primary students (including 1,612 males and 1,085 females) and 182 secondary students (including 145 males and 37 females).



How a Lack of Green Infrastructure Increases School Temperatures

Table 67 District-Level Breakdown of Public-School Students in Al Mukalla (2025)

District	Primary			Secondary		
	Male	Female	Total	Male	Female	Total
Hadramout (Al Mukalla City)	23395	27488	50883	5658	6256	11914
Hadramout (Al Mukalla Rural)	1,612	1,085	2,697	145	37	182
Aden	62920	61888	124808	16452	13073	29525

5..3 Climate Change Effects on Education Environment

In a country where over 16 million people, including 8.47 million children, urgently need water, sanitation, and hygiene (WASH) assistance, clean drinking water is vital for students and their families[23]. Lack of potable water further compounds climate risks. Many schools face chronic shortages of potable water and lack access to functional sanitation facilities. This elevates the risk of waterborne diseases and hygiene-related illnesses, especially in hot, overcrowded schools' environments where basic handwashing and

sanitation are not consistently available. These WASH deficits directly threaten student health, attendance, and retention, particularly for girls.

These vulnerabilities are further intensified by the accelerating impacts of climate change, particularly in coastal and lowland governorates such as Aden, Hadramout (Al-Mukalla), and Al-Hodeidah[24]. These regions are experiencing rising temperatures, increasingly frequent and intense heatwaves, and unreliable access to critical public services, including electricity and water[22]. Climate and environmental challenges significantly hinder access to education, leading to low retention rates and poor learning outcomes in basic education. These issues reflect broader patterns of poverty, geographical disparities, gender inequities, disability, and the impacts of conflict and displacement. Currently, among 10 million school-aged children (ages 5–17), approximately 20% are not enrolled in school[25], while 1.3 million face overcrowded classrooms and overburdened teachers[26]. This situation limits human capital development for the youth and restricts productive engagement for women, undermining the effectiveness of climate change adaptation efforts[26].

Broader climate-linked socioeconomic pressures are also undermining educational outcomes. Communities across Yemen are increasingly affected by conflict-related displacement, extreme weather events, and deteriorating livelihoods. Food insecurity remains widespread; as of 2025, the World Food Programme (FAO) reports that nearly half of Yemen's population is acutely food insecure[27],. Among school-aged children, undernutrition, driven in part by climate impacts on agriculture and household income, is strongly correlated with poor cognitive development, lower school performance, and higher dropout rates[27]. Malnutrition delays physical and mental growth, reduces academic capacity, and presents long-term barriers to educational attainment and well-being.

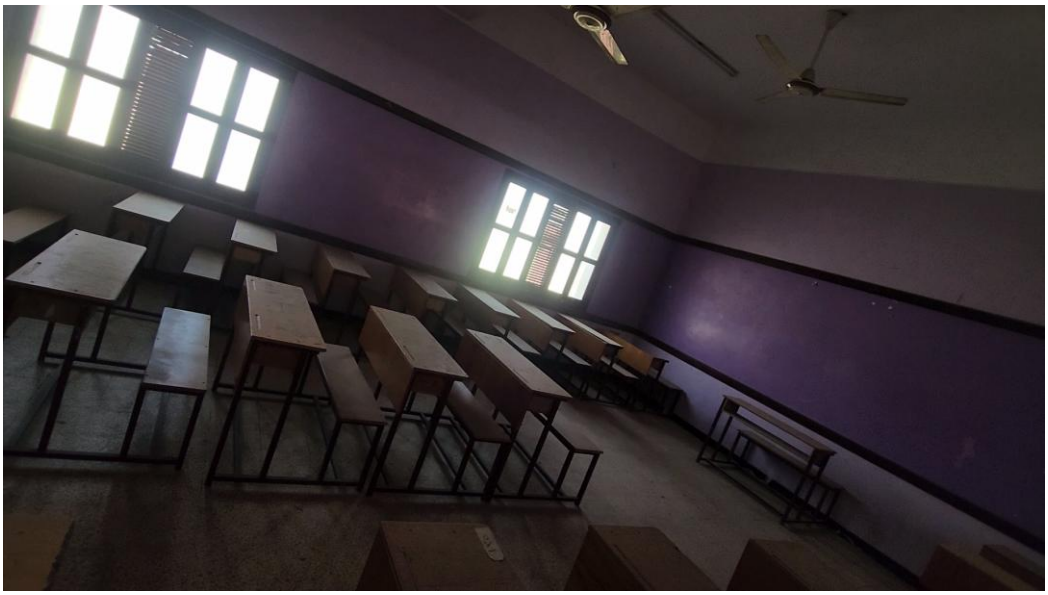
Furthermore, in these hot and arid environments, only 51% of schools provide access to safe water for drinking, sanitation, and hand hygiene, which significantly heightens the vulnerability of students[25].

5..4 Climate Profile and Its Impact on Learning Environment in Hadhramaut

As illustrated in Chapter 2.3, the impacts of climate variability and environmental degradation are increasingly evident across Yemen's education sector. Initial field assessments conducted in the governorates of Aden, Al-Hodeidah, and Hadramaut revealed an education system operating under severe environmental and infrastructural stress. The combined effects of rising temperatures, water scarcity, unreliable electricity, and inadequate school infrastructure are systematically undermining educational access, quality, and learning outcomes. The assessments identified a series of climate-related challenges directly affecting schools, teachers, and students, including:

- Extreme Heat Exacerbated by Infrastructure and Overcrowding: Field teams recorded classroom temperatures consistently higher than outdoor ambient levels, averaging around 36°C in Aden, 37°C in Al-Hodeidah, and reaching up to 40°C in Al-Mukalla during peak midday hours. Poor ventilation, heat-retaining structures, and severe overcrowding contribute to these conditions, creating uncomfortable learning environments that visibly affect students' concentration and well-being.
- Severe Overcrowding Intensifying Heat and Health Risks: Direct field assessments confirmed extreme levels of student overcrowding, with urban classrooms in Aden accommodating an average of 70–100 students, nearly double the national standard. In Al-Hodeidah, large schools such as the 22-May School were found to be serving over 3,000 students within limited infrastructure. This

level of congestion traps heat, restricts air circulation, and significantly heightens the risk of heat stress and communicable illnesses among students and teachers alike.



Poor Natural Lighting in Classrooms at Midday – Mukalla School

- Direct Operational Disruptions and Health Incidents: Assessments confirmed the operational and health consequences of heat and infrastructure deficiencies. The widespread use of double-shift systems forces students to attend classes during the hottest hours of the day, exposing them to unsafe thermal conditions. Field teams documented frequent class suspensions due to extreme heat and power outages. In Hadramaut, education authorities and school management reported the severe effects of the 2023 heatwaves, which led to multiple incidents of fainting and heat-related illnesses among students and staff. In response, schools implemented adaptive scheduling, including the cancellation of morning assemblies and shortened afternoon sessions. Similar disruptions were recorded in Aden (2021) and Hadramaut (2024) due to extreme weather events.



Classroom Environment: The Effect of Solid Iron Windows on Light and temperature

- Critical WASH Facility Failures and Water Scarcity: Field observations revealed critical deficiencies in WASH (Water, Sanitation, and Hygiene) infrastructure, compounded by chronic water scarcity. Many schools lacked reliable access to clean water, functional sanitation facilities, and basic hygiene supplies. These shortcomings undermine health, attendance, and hygiene, while humid climatic conditions further exacerbate sanitation-related risks.



Widespread Inadequacy of WASH Infrastructure in Schools

- Degraded Air Quality and Indoor Discomfort: Overcrowded classrooms with no mechanical ventilation result in stagnant air, high humidity, and CO_2 buildup, aggravating respiratory issues and reducing overall comfort and concentration.
- Deterioration of School Infrastructure: Continuous exposure to heat and humidity accelerates the degradation of buildings, including roof cracking, paint deterioration, and corrosion of metal fixtures and learning equipment.
- Insufficient Access to Safe Drinking Water: Limited or intermittent water supply forces students to rely on unsafe sources, heightening risks of dehydration and waterborne diseases.
- Increased Gender-Based Disparities: Girls are often kept home during water-scarce periods due to inadequate WASH privacy and poor sanitary conditions, exacerbating gender gaps in education.
- Limited Adaptive Capacity: Most schools lack the institutional and technical capacity to manage climate-related stress, constrained by unreliable electricity, limited maintenance budgets, and absence of school-level emergency or heat management plans.



The Imperative for Capacity Building in Climate-Resilient Practices: Learning from Maladaptive

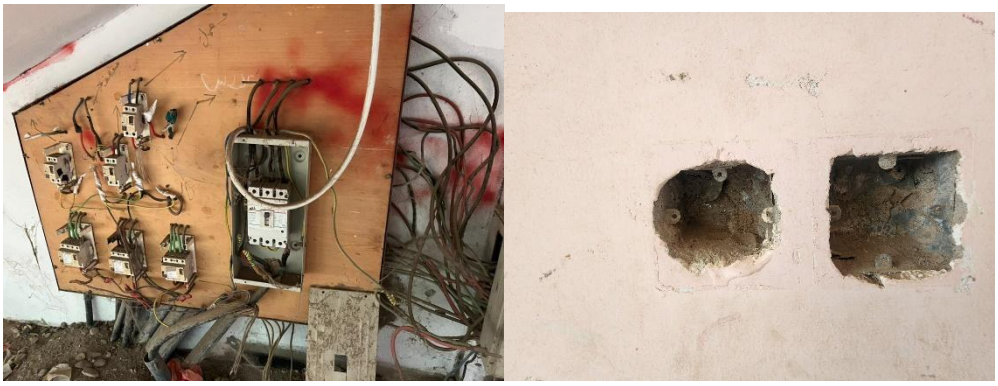
5..5 Electricity Crisis Impact on Education Environment

As illustrated in Chapter 5.1, the targeted governorates have faced severe and prolonged electricity shortages, with residents enduring recurrent shutoffs of both water and power. In Aden and Hadramaut, the situation has worsened over recent years. By June 2023, publicly supplied electricity was available for as little as 2–3 hours per day[22], rising modestly to 4–6 hours daily during July and August 2023. By mid-2025[28], field observations confirmed that blackouts had intensified, with average outage durations exceeding 19 hours per day, leaving many households with barely 90 minutes of grid power.

In Al-Hodeidah, the public electricity grid is non-functional, forcing schools and households to work without electricity sources. The absence of reliable electricity has a direct and severe impact on the learning environment: classrooms become unbearably hot, with no ventilation or lighting, resulting in student discomfort, health risks, and diminished academic performance.

The absence of reliable electricity severely undermines the resilience of educational institutions to climate-related shocks. It also impedes the delivery of essential services such as lighting, ventilation, digital learning tools, and water pumping systems, factors that are increasingly critical in the face of rising temperatures and prolonged power outages. These challenges contribute to worsening learning conditions, reduced student attendance, and heightened disparities for children in already marginalized communities. A field visit provided a critical snapshot of the electricity access landscape in schools across Al Mukalla City, Al Mukalla Rural District, and Al-Hodeidah southern districts highlight significant gaps in access to reliable and sustainable electricity, indicated the following critical energy-related challenges in schools:

- School electricity infrastructure: Many school electrical systems are non-functional or unsafe due to conflict damage, prolonged long-term non-operation, and a lack of maintenance. Major repairs or complete upgrades are a prerequisite for any new electrification or solar PV projects.



Non-functional and unsafe electrical infrastructure in schools is due to conflict damage, prolonged long-term non-operation, and a lack of maintenance.

- Low-efficiency lighting: Approximately 90% of classrooms use 40–70 W incandescent or low-efficiency bulbs.
- Inefficient cooling systems: Fans in classrooms are typically 80–100 W units, often insufficient in number and poorly maintained, limiting effective air circulation.
- Inadequate fan coverage: Many classrooms have too few fans to provide cooling for all students, particularly in overcrowded rooms.



Inefficient Classrooms Lighting and Cooling Fans

The absence of reliable electricity severely undermines the resilience of schools to climate stressors. With rising average temperatures and more frequent, prolonged heatwaves, schools without functional energy systems struggle to provide safe and conducive learning environments. The lack of power prevents the use of fans, lighting, and water pumps, and hinders basic digital education. As a result, student health, attendance, and learning outcomes are adversely affected—particularly for girls and children in the most underserved areas.

During the last years, multiple solar PV systems were deployed in some public schools. International actors (EU, UNDP, UNOPS, UNICEF, World Bank) collaborated with local authorities and NGOs to deliver these

systems under projects such as EU's SIERY and World Bank's YEEAP, Global Giving funded projects, as well as certain initiatives funded separately. Although fragmented information indicates several initiatives aimed at establishing schools across various regions of Yemen, comprehensive data on most of these initiatives remain unavailable and unorganized. It is estimated that fewer than 10% of the schools in Yemen currently utilize solar energy.

While recent solar electrification efforts represent important progress, they remain limited in scale and do not sufficiently address the growing climate-related challenges facing educational infrastructure in Yemen. With rising temperatures and the increasing frequency of heatwaves, many schools continue to experience unsafe indoor environments, unreliable electricity supply, and poor adaptive capacity to climate extremes.

To strengthen climate resilience, future interventions must adopt an integrated approach that goes beyond energy access. This includes the incorporation of passive cooling techniques (such as improved natural ventilation, shaded outdoor spaces, and heat-reflective roofing), access to water through solar-powered drinking water pumping systems, and enhancements to building envelopes. These measures, when combined with decentralized renewable energy solutions, will improve thermal comfort, improve student wellbeing, and reduce learning disruptions during extreme weather seasons.

On the same side, findings underscore the close interdependence between education infrastructure and adjacent water supply systems. Many schools share water sources with surrounding communities, and the failure of these systems due to energy insecurity directly affects WASH services within the schools themselves. As such, the project presents an opportunity to adopt a more integrated resilience-building approach by assessing solar PV options for both schools and essential water infrastructure. This not only enhances the adaptive capacity of vulnerable populations but also reinforces the sustainability and efficiency of interventions.

In addition to their adaptation function, RE and EE solutions offer mitigation co-benefits by lowering greenhouse gas emissions associated with diesel use. They also deliver tangible socioeconomic dividends, such as reducing operating costs, minimizing maintenance burdens, and supporting long-term educational continuity in fragile and climate-vulnerable regions.

6.1 Electricity Crisis Impact on Water Security

Reliable and affordable energy is the backbone of Yemen's water security. Every aspect of water service delivery, pumping, treatment, distribution, and desalination depends on continuous power supply. In the absence of stable electricity, utilities struggle to provide safe drinking water and sanitation, forcing communities to rely on costly diesel generation or water trucking. The heavy dependence on diesel is not only financially unsustainable but also environmentally damaging, contributing to greenhouse gas emissions and exposing water systems to supply chain disruptions. Scaling up renewable energy is therefore central to ensuring reliable water services, protecting public health, and strengthening resilience in a fragile and climate-vulnerable country.

Across Yemen, total energy consumption for water utilities between 2014 and 2023 averaged **≈108.25** million kW per year, with a cumulative demand of more than 1.08 billion kW over the past decade. In 2023 alone, the total power required for operation exceeded 108 million kW, reflecting both population growth and rising service needs. Despite donor support, this demand is still largely met through diesel generation, with only a fraction supplied by grid electricity and a modest but growing contribution from solar. This

reliance on diesel—expensive, polluting, and prone to disruption—underscores the urgency of accelerating the fuel exit strategy and scaling renewable energy solutions.

Al Mukalla has the largest demand profile in the portfolio. Actual energy used peaked at ≈21,532,195 kW in 2023 (annual average ≈15.8M kW; 2015 low ≈12.66M kW), while the total power required for operation that year reached ≈36,993,109 kW—implying a gap of ≈15.46M kW that is currently bridged by unreliable sources and efficiency losses. The trend line points to steady growth and highlights the need to tighten energy management and accelerate non-diesel supply to meet rising water-service loads.

Aden: Aden's total energy consumption first appears in 2021 (≈43.10M kW), surges in 2022 (≈198.94M kW), then moderates in 2023 (≈167.57M kW)—a three-year swing that underscores operational volatility and rapid scale-up. Within the mix, grid electricity rose from ≈9.64M kW (2021) to ≈15.28M kW (2023), while solar climbed from ≈239,224 kW (2021) to ≈1,202,125 kW (2023). Monthly distribution data still show a diesel-heavy baseline (≈676,823 kW/month from generators vs ≈383,425 kW/month from network+solar), even as the utility reports sufficient land to host additional PV at wells and waterfields.

Grid use in Abyan was absent until 2020, then recorded ≈8.14M kW (2020), ≈4.95M (2021), ≈5.49M (2022), and jumped to ≈18.33M kW (2023)—a +234% year-over-year rise from 2022 to 2023 that likely reflects restored service and donor support. On the diesel side, the utility's fuel needs trend downward in the long run—≈75,000 L (2014) → ≈30,000 L (2023) (with a spike to ≈140,000 L in 2021), and diesel energy use first appears around ≈844,357 kW (2021–2022). Together, these data suggest Abyan's current supply is grid-led with reduced diesel dependency, but the volatility in recent years warrants tighter monitoring and targeted solar/hybrid additions to stabilize operations.

In Shabwah the total power required in Ataq stayed near ≈3,087,900 kW through 2019 and rose to ≈4,270,500 kW in 2023, while solar use expanded from ≈292,000 kW (2016) to ≈1,100,000 kW (2023) (+276.7%). Even so, the monthly split indicates continuing diesel dominance (≈246,600 kW/month from generators versus ≈73,620 kW/month from the grid), though asset data show a growing base of hybrid and solar wells (e.g., ≈7 hybrid, 13 solar, 13 grid-connected). The implication for Shabwah is clear: PV/hybrid deployment is underway and scaling, but diesel displacement and reliability gains will require further PV build-out at wellfields and systematic energy-efficiency measures.

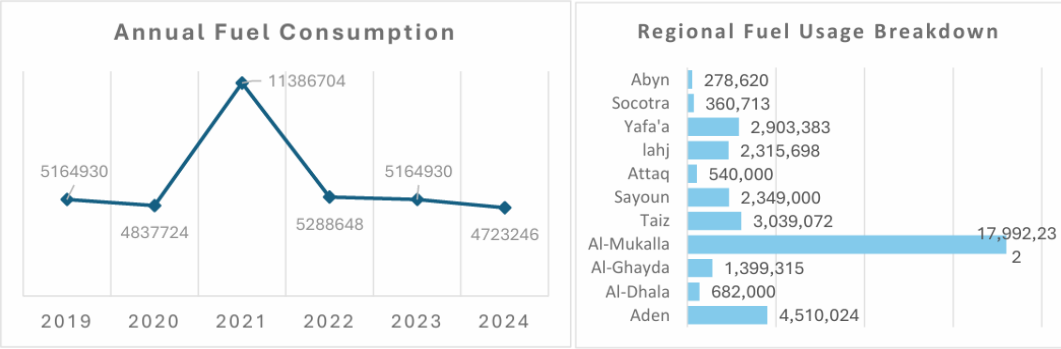


Figure 60: Energy Consumed by Local Water and Sanitation Cooperations (LWSCs)

In this challenging context, solar-powered pumping presents a promising adaptation. Yemen benefits from some of the highest solar irradiance levels in the world, averaging 5.2 - 6.8 kWh/m² per day, which makes PV pumping systems highly efficient. A solar PV pump converts abundant sunlight directly into motive

power, eliminating the need for fuel and dependence on the grid. Unlike diesel generators or limited electric grids, solar pumps provide free energy once installed, with minimal ongoing energy costs.

The long-term sustainability of solar pumps is one of their key advantages. Although the initial investment in solar pumping systems may be high, operational costs are significantly lower than those associated with diesel-powered systems. Diesel pumps require fuel, which is both expensive and often difficult to obtain in remote areas, while solar pumps rely on free and abundant solar energy. Over time, the savings on fuel and maintenance costs make solar pumps a financially viable solution, particularly in areas where water extraction is essential for agriculture and drinking water.

In addition to the cost-effectiveness, solar water pumps are relatively low-maintenance compared to diesel pumps, which require frequent servicing and replacement of parts. Solar pumps typically have fewer moving parts, and the absence of fuel-based components reduces wear and tear.

In terms of GHG emissions, solar water pumps offer a low-carbon solution to water extraction, making them a crucial element of Yemen's broader climate change mitigation strategy. Solar water pumps contribute to a significant reduction in the country's overall carbon emissions, thus promoting a transition toward a cleaner and more sustainable energy future. By replacing diesel-powered pumps, solar pumps could help reduce GHG emissions from the water sector, which is a significant emitter due to the reliance on fossil fuels.

5..1 Fuel Exit Strategy for Yemen's Water and Sanitation Sector (2024-2030)

The Ministry of Water and Environment in Yemen, through its local water corporations and utilities, has developed a Fuel Exit Strategy to reduce reliance on fossil fuels in the water and sanitation sector. The strategy aims to transition to renewable energy sources, primarily solar and wind, addressing challenges such as high operational costs, environmental impact, service interruptions, and financial strain caused by fluctuating fuel prices, supply disruptions, and carbon emissions. The strategy provides a practical roadmap for a sustainable shift to renewable energy, focusing on Yemen's renewable energy potential. The transition will be implemented over seven years (2024-2030) in three phases.

Phase 1: Assessment and Planning (Years 1-2)

In the first phase, the strategy emphasizes comprehensive assessments of existing fuel usage and the energy needs of water and sanitation facilities. This phase also includes evaluating the technical, financial, and management capabilities of local water utilities to ensure the feasibility of adopting renewable energy systems.

Key activities include conducting an energy needs analysis to establish a baseline for energy consumption, evaluating the institutional capacity of local water utilities, and performing site surveys to identify areas with optimal solar radiation and wind potential for renewable energy installations. Additionally, this phase involves project planning and budgeting, including the development of technical specifications, detailed project plans, and an action plan to strengthen the capabilities of water utilities.

The expected deliverables from this phase will include a comprehensive energy assessment report, which will provide an in-depth analysis of the current energy usage and needs across water and sanitation facilities. Additionally, a list of high-potential sites for renewable energy installations will be generated based on site surveys and resource assessments. The phase will also result in a detailed institutional and technical capabilities report, evaluating the readiness of local water utilities to adopt and manage renewable energy

systems. Finally, the phase will culminate in the development of detailed project plans, which will outline technical specifications, project timelines, and budgets for the upcoming pilot projects and necessary upgrades to infrastructure.

Phase 2: Pilot Projects and Capacity Building (Years 2-4)

Building on the assessments from Phase 1, the second phase focuses on implementing pilot projects to test renewable energy systems. This phase will also prioritize strengthening the capacity of local staff for the effective operation and maintenance of these systems. The key activities will involve installing solar-powered water pumping systems and wind turbines in high-potential areas, such as coastal regions. Additionally, training programs for local engineers and technicians will be developed to ensure long-term sustainability. A robust monitoring framework will be established to assess the performance of these projects, focusing on energy production, cost savings, and reliability. Knowledge-sharing workshops will also be organized to disseminate lessons learned and best practices for scaling up renewable energy adoption.

This phase will include the installation and successful operation of pilot renewable energy systems, along with evaluation reports to assess their performance. Training materials and certification records will be created to equip local staff with the skills to manage the systems. Additionally, the rehabilitation and maintenance of existing water and sanitation infrastructure will be carried out to ensure long-term sustainability.

Phase 3: Scaling Up and Integration (Years 5-7)

This phase aims to scale successful pilot projects to additional sites, integrate renewable energy systems into existing infrastructure, and establish long-term partnerships for funding and technical support.

Key activities involve identifying and prioritizing new sites for renewable energy system expansion based on pilot project outcomes and renewable energy potential. Diesel generators will be replaced with renewable energy systems in existing infrastructure to reduce fuel consumption and improve sustainability. Efforts will also focus on rehabilitating water supply systems and enhancing the capabilities of local water utilities. Partnerships will be established with international donors, NGOs, and private companies to secure funding and technical support for large-scale implementation, while collaborative projects will be pursued to further expand and integrate renewable energy systems.

The expected outcomes include the expansion of renewable energy systems to additional sites, the successful integration of these systems into existing infrastructure, and the establishment of long-term partnerships and funding arrangements to ensure sustainable implementation.

6.1 Diesel generator greenhouse gas emissions in LSWC

Based on the Fuel Exit Strategy (2024–2030), Yemen's water sector remains heavily reliant on aging diesel-powered generators for water extraction, treatment, and distribution. These generators face critical challenges, including high maintenance costs, reduced efficiency, and significant environmental impact. Older units tend to consume more fuel, break down frequently, and require escalating maintenance, all of which drive up operational expenses.

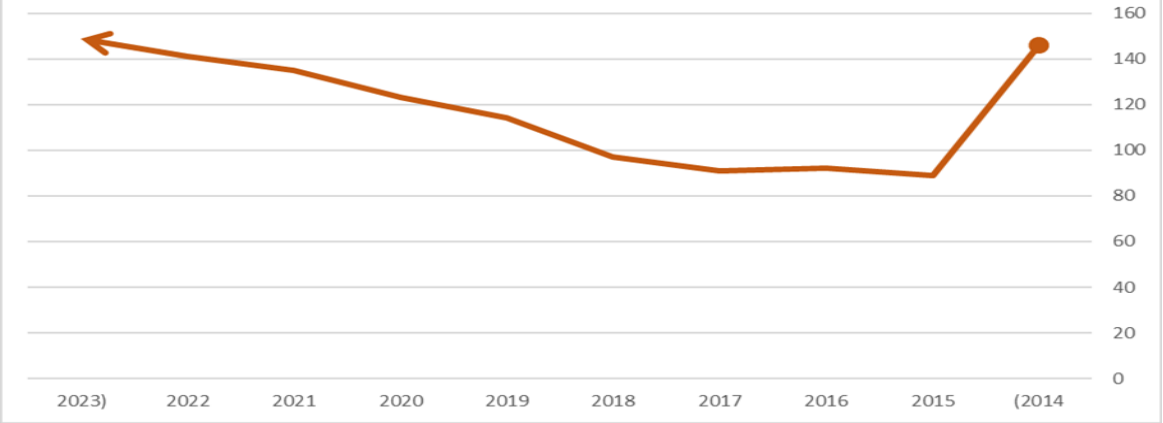


Figure 61. Generators of water and wastewater utilities MWE supervision (Aden)

As shown in Figure 61, the total number of generators used in Yemen's water and wastewater utilities under the supervision of the MWE Aden increased only slightly from 146 in 2014 to 149 in 2023, reflecting a 2.05% overall growth[29]. This modest increase, when viewed alongside the gradual rollout of solar PV systems, highlights uneven infrastructure expansion relative to population growth. It also underscores the continued challenge of delivering water services in an efficient and sustainable manner.

Mukalla LWSC expanded its genset from 34 in 2014 to 41 by 2020, a 20.6%[29]. In contrast, Aden LWSC registering generators in 2021, with 5 units recorded through 2023[29].

The analysis of diesel consumption across Yemen's water utilities between 2014 and 2023 highlights substantial and fluctuating energy demands, heavily influenced by the availability of donor subsidies, particularly after 2018[29]. For instance, Mukalla LWSC recorded a sharp rise in diesel requirements starting in 2018, averaging approximately 5.9 million liters per year—a trend that persisted through 2023, reflecting increased operational strain amid limited grid access. In contrast, several other branches either lacked consistent subsidy support or had significant data gaps, impeding a comprehensive assessment of their diesel needs[29].

Parallel to this, the escalating value of oils and lubricants used in generators and pumps further illustrates the utilities' unsustainable dependence on diesel-based systems. The total value of oils/lubricants across all LWSCs rose from SAR 157 million in 2014 to SAR 149 million in 2023, with a cumulative subsidy-driven increase of 407.31%. Notable examples include Ataq, where expenditures surged from SAR 500,000 in 2014 to over SAR 14 million in 2023, and Aden, which witnessed a dramatic leap from SAR 11 million in 2021 to SAR 92 million in 2022 alone[29]. These figures underscore the growing operational burden placed on already fragile utilities and reinforce the urgent need for transitioning toward renewable energy solutions to enhance service continuity[29].

In term of electricity consumption, the data reveals significant variations among utilities. Aden, for example, saw a dramatic rise in energy use to over 21.5 GWh in 2021, peaking at nearly 99.5 GWh in 2022 before dropping to approximately 83.8 GWh in 2023[29]. Mukalla LWSC reported the highest average annual energy consumption, at around 15.8 GWh[29].

This continued use of diesel generators exacerbates environmental concerns due to their high emissions compared to cleaner energy alternatives. Transitioning to renewable energy sources, such as solar and hybrid systems, offers a viable solution to reduce fuel dependency, enhance operational efficiency, and mitigate environmental harm. Implementing these technologies will not only lower operational costs but also help curb greenhouse gas emissions, aligning with Yemen's broader environmental sustainability goals.

6.1 Solar-Powered Drinking Water Pumps in Aden and Al-Mukalla

The deployment of solar-powered systems for drinking water remains in its early stages, drinking water utilities have been forced to shift to solar PV systems to reduce dependency on fossil fuels, driven by the unsustainability of subsidized fuel supply and ongoing fuel crises, along with donor-supported energy programs. An analysis of solar PV usage in the governmental drinking water sector from 2014 to 2023 reveals a clear upward trend in several utilities, though there is notable variation in adoption levels across governorates[29].

In this early adoption phase, a few utilities, such as Taiz, Mukalla, Aden, and Ataq demonstrated increases in solar energy consumption, signaling successful integration into operations and tangible progress toward energy efficiency[29]. Others, like Al-Dhale and Seiyun, have only recently begun to adopt solar technologies but show promising initial results. In 2021, Mukalla LWSC's solar energy use was approximately 0.3 GWh, which surged to over 1.25 GWh in 2022. Aden LWSC also demonstrated strong growth: starting from 0.24 GWh in 2021, it increased fivefold to 1.2 GWh by 2023[29].

Three major installed projects mark a significant shift toward integrating renewable energy into public water infrastructure as a means of reducing fuel dependency, stabilizing service delivery, and strengthening climate resilience.

In Al-Mukalla, UNICEF Yemen completed a 1-megawatt solar-powered water pumping project at the Zaman water well field in early 2024[30]. The system was designed to supply reliable, off-grid energy for the city’s largest drinking water source, ensuring access to safe water for over 250,000 residents[30]. This initiative addressed years of intermittent supply due to chronic grid failure and diesel shortages. As one of the largest urban-scale WASH solar projects in Hadramout, it demonstrates the viability of using large-format solar PV systems in dense coastal settings[30].

In Aden, two separate solar water pumping systems have been installed. The first is located at the Bir Nasser water station, where a solar array exceeding 1 MW capacity has been commissioned under the World Bank’s Emergency Human Capital Project, implemented by UNOPS and overseen by the Urban Water and Sanitation Project[31]. The system includes full automation, remote monitoring, and diesel integration to ensure continuous service delivery[31]. Complementing this, the Kuwait Fund for Arab Economic Development financed the installation of a 600 kW solar-powered water pumping system benefits more than one quarter million residents[30].

6.1 DRE Priority Interventions and Cross-Cutting Measures

This section outlines a strategic framework for DRE deployment, designed to address the most critical needs identified in the energy, education, and drinking water sector. It moves beyond simply providing

electricity to leveraging it as a catalyst for improving learning environments, securing water access, and strengthening community resilience. The proposed interventions are deliberately integrated, recognizing that schools are community anchors, that water security is a prerequisite for health and stability, and that reliable energy is the backbone of climate adaptation and economic activity:

1. **Green Schools –** deploying renewable energy, energy efficiency, greening, and water security measures to create safe, climate-resilient learning environments. Schools will be directly powered by solar systems and equipped with ventilation and cooling technologies to protect students' health, while also ensuring access to safe drinking water through desalination and water treatment.
2. **Solar Mini-Grids with Schools as Community Hubs** – developing decentralized solar mini-grids that not only power schools but also extend energy access to surrounding communities. Schools will function as hubs for providing clean energy that supports water security, resilient facilities, and essential services. They will also serve as entry points to power livelihoods and enhance adaptive capacity by enabling broader energy access for vulnerable households.
3. **Solar Productive Use for Water Security and Climate-Resilient Livelihoods** – deploying renewable-powered water pumping, desalination, and treatment systems, alongside productive-use applications that sustain and strengthen livelihoods. This includes renewable-powered post-harvest processing, storage, and value-chain development for key cash crops such as palm dates, honey, and sesame. By improving water security and reducing post-harvest losses, this intervention enhances income diversification, food security, and resilience for vulnerable communities, particularly women and youth.

Each intervention is carefully tailored to the urban, peri-urban, and rural contexts of Aden, Al-Hudaydah, and Al-Mukalla, ensuring that education, water security, energy access, and livelihoods are integrated into a holistic approach that responds to both urgent humanitarian needs and long-term climate resilience.

5..1 Intervention 1: Green Schools

This intervention will establish Green Schools as climate-resilient, self-sufficient educational hubs by deploying integrated renewable energy, energy efficiency, green infrastructure, and institutional capacity-building measures. The intervention will directly reduce schools' reliance on fossil fuels, safeguard students' health against extreme heat, and ensure continuity of education during climate shocks. The Green school's intervention will:

- Install decentralized renewable energy systems through off-grid solar PV with battery storage, designed to power classrooms, lighting, fans, WASH pumps, and ICT/computer labs.
- Replace inefficient equipment with energy-efficient technologies, including LED lighting, high-efficiency fans, and optimized electrical appliances to reduce system load and extend PV-battery performance.
- Integrate green infrastructure by establishing shaded courtyards, planting climate-resilient trees, and constructing rainwater harvesting systems to enhance thermal comfort, improve stormwater management, and support WASH.
- Deliver capacity-building programs by equipping school staff, students, and community members with training on system operation, maintenance, and green practices, alongside vocational learning modules for renewable energy installation and repair.

The Green Schools Initiative will enable schools to remain operational during extreme climate events,

providing safe and conducive indoor environments for students who are highly vulnerable to heat stress, dehydration, and related health risks. By ensuring reliable renewable-powered electricity, schools will maintain lighting, cooling, and digital learning facilities, significantly improving educational quality, student well-being, and overall attendance. In addition, renewable-powered WASH systems will secure access to clean drinking water, protecting student health and ensuring continuity of essential services within schools.



Figure 62:Green Schools Model

The intervention will also generate environmental and socio-economic co-benefits. By displacing diesel generation, it will reduce fossil fuel dependency and greenhouse gas emissions, contributing to climate mitigation. Greening measures such as shaded spaces and tree planting will enhance thermal comfort, reduce heat stress, and improve air quality within school compounds. The initiative will further create new employment opportunities in renewable energy and green infrastructure, while building the technical capacity of teachers, students, and community members to operate and maintain these systems. Importantly, it will advance gender equity and social inclusion by prioritizing the participation of women and internally displaced persons in training, technical roles, and school-level leadership. Taken together, these benefits will not only safeguard the education system but also protect the health of students, while establishing a replicable model for resilient, low-carbon educational infrastructure tailored to Yemen's fragile and climate-vulnerable context.

5..2 Intervention 2: Solar Mini-Grids with Schools as Community Hubs for Climate Resilience and Development

This intervention will establish solar mini-grids anchored around green schools to serve as community resilience hubs, delivering reliable energy for education, health, water security, and livelihoods in rural and peri-urban areas. By decentralizing energy supply, the intervention will reduce dependence on fossil fuels, strengthen rural resilience against climate shocks, and promote inclusive socio-economic development. The Solar Mini-Grids with Schools as Hubs intervention will:

- Deploy solar PV mini-grids scaled between 50–200 kW depending on community size, integrated with advanced battery storage or hybrid options to ensure continuous supply.

- Connect schools, health posts, and community facilities to guarantee uninterrupted electricity for education, healthcare, and essential community services.
- Support water security by powering solar-based WASH facilities, drinking water systems, and desalination and treatment units, ensuring safe and climate-resilient water access for both schools and surrounding communities.
- Enable climate-resilient livelihoods and value chains by providing reliable power for agro-processing, cold storage for crops, fisheries and vaccines, tailoring, food processing, and other micro-enterprises. This will strengthen key cash crop value chains such as palm dates, honey, and sesame, while creating opportunities for women- and youth-led businesses and diversifying household incomes.



Figure 63:Green School and Community Hub Model

The Solar Mini-Grids intervention will transform rural energy access by providing reliable, affordable, and clean electricity in areas where grid extension is limited or is not feasible. It will enable schools to function as dual-use facilities—both learning centers and resilience hubs—ensuring continuity of essential services, including water and sanitation, during climate extreme events. At the same time, it will reduce greenhouse gas emissions by displacing diesel generation, create opportunities in renewable energy, and increase women's participation in energy-enabled livelihoods. Together, these measures will stabilize rural populations by reducing climate-induced migration and establish a replicable model for decentralized electrification in Yemen's fragile and climate-vulnerable context.

5..3 Intervention 3: Solar Productive Use for Water Security and Climate-Resilient Livelihoods

This intervention will deploy solar-powered productive use technologies to strengthen agricultural and fisheries value chains, enhance food security, and improve water-energy resilience in climate-vulnerable communities. By replacing diesel-based systems with reliable solar solutions, the intervention will reduce post-harvest losses, lower energy costs, and stabilize livelihoods while ensuring continuous access to clean water in both rural and peri-urban areas.

- Install solar-powered agro-processing technologies such as dryers, mills, and grinders to reduce post-harvest losses, add value to agricultural products, and increase farmer income.
- Deploy solar-powered cold storage units for perishable crops and fisheries products, ensuring product quality, extending shelf life, and strengthening food security for vulnerable communities.
- Expand solar PV systems in Local Water and Sanitation Cooperations (LWSCs) in Ade to power water pumping, desalination, treatment, and distribution facilities, directly addressing unreliable grid power and high diesel costs. This will form part of a broader fuel exit strategy in the water sector, enabling a shift away from diesel dependence while securing reliable, climate-resilient water services.



Figure 64:Solar Energy for water Security and Livelihoods

The Solar Productive Use intervention will strengthen climate-resilient livelihoods by supporting smallholder farmers, fisherfolk, women-led enterprises, and cooperatives with renewable-powered tools to stabilize income and reduce vulnerability to climate risks. It will also secure reliable water supply for households and agricultural activities by expanding solar energy in LWSC operations, including desalination units, lowering operational costs, and ensuring service continuity during climate disruptions. At the same time, the intervention will displace diesel-powered milling, cold storage, fisheries preservation, and water pumping, cut greenhouse gas emissions and improving local air quality. By targeting women, youth, and vulnerable groups, the intervention will advance gender equality, promote inclusive participation in agricultural and fisheries value chains, and build stronger community resilience. Collectively, these measures will create a replicable model for integrating renewable energy into productive use and water infrastructure, while accelerating Yemen's transition toward a fuel exit strategy in the water sector and a low-carbon, climate resilient future.

5..4 Intervention 4: Enabling Environment for Sustainable Deployment of DRE Interventions

The success of the three decentralized renewable energy interventions depends on a strong enabling environment that reduces risks and ensures sustainability. A de-risking framework for off-grid and mini-

grids in Yemen is essential to address challenges of fragility, investment risks, and system performance. Supportive policies, technical standards, and streamlined permitting processes will help integrate renewable-powered education, water, and livelihood systems into national energy and climate strategies.

Equally important is the development of sustainable business models tailored to schools, community mini-grids, and productive-use applications. These models will balance affordability with long-term cost recovery, enabling schools to function as resilience hubs while ensuring water utilities and local enterprises can sustain operations without dependence on diesel. Public-private partnerships and innovative financing tools, including climate finance, will mobilize the resources needed to scale these interventions.

Finally, the project will invest in feasibility studies, technical assessments, and capacity-building to ensure systems are designed to meet actual demand and are properly managed. Training for school staff, local technicians, and water cooperations will strengthen operations and maintenance, while community governance mechanisms will foster ownership. Together, these measures will create the institutional, financial, and technical foundations for Green Schools, Solar Mini-Grids, and Solar Productive Use systems to operate effectively and be replicated across Yemen's fragile and climate-vulnerable context

Table 68:Comparison between the three interventions

Intervention	Core Focus	Key System Components	Primary Benefits	Target Groups
1. Green Schools	Schools as climate-resilient, self-sufficient hubs for education	- Off-grid solar PV with storage for classrooms, ICT labs, fans, and WASH pumps - Energy-efficient equipment (LED, high-efficiency fans) - Green infrastructure (shade, trees, rainwater harvesting) - Capacity-building for O&M and vocational training	- Continuous learning during climate extreme heatwaves - Improved student health and well-being - Safe drinking water in schools - Reduced GHG emissions - Local jobs and gender inclusion	Students, teachers, school staff, IDPs, women, youth
2. Solar Mini-Grids with Schools as Community Hubs	Schools as anchors for community-wide energy access and services	- Solar PV mini-grids (50–200 kWp) with advanced storage - Connections to schools, health posts, community facilities - Power for WASH, drinking water, desalination, treatment - Productive use for agro-processing, cold storage, fisheries, micro-enterprises - Community governance structures	- Reliable energy for education, health, and community services - Strengthened water security - Expanded livelihoods and value chains (palm dates, honey, sesame, fisheries) - Reduced diesel dependency and GHG emissions - Stabilized rural populations, reduced climate migration	Schools, households, water facilities, women- and youth-led enterprises, vulnerable rural and peri-urban communities
3. Solar Productive Use for Water Security & Climate-Resilient Livelihoods	Solarization of productive-use applications and water infrastructure	- Solar agro-processing (dryers, mills, grinders) - Solar cold storage for crops & fisheries - Solar PV for LWSC facilities (pumping, desalination, treatment, distribution) - Community-based O&M models (cooperatives, women's groups, fisheries associations)	- Reduced post-harvest losses & improved food security - Reliable, low-cost water supply through solarized LWSCs - Strengthened agricultural & fisheries value chains - Reduced diesel use and GHG emissions - Income diversification, women & youth empowerment	Smallholder farmers, fisherfolk, women-led enterprises, cooperatives, LWSCs, urban & peri-urban communities
Intervention 4: Enabling Environment for Sustainable Deployment of DRE Interventions				

6.1 List of Interventions in the targeted governorates and districts

Table 69:List of interventions

Intervention Category	Governorates / Locations	Intervention / Project Output	Description	Climate Rationale
Green Schools	Aden, Al-Hudaydah, Al-Mukalla	Deployment of renewable energy, energy efficiency, greening, and WASH systems in schools (Output 3.1 & 3.2)	Install off-grid solar PV with storage, replace inefficient appliances, add green/shaded infrastructure, and establish renewable-powered WASH systems. Capacity-building for staff and students included.	Ensures safe, climate-resilient learning environments, protects student health from extreme heat, secures water access, reduces GHG emissions, and builds adaptive capacity in the education sector.
Solar Mini-Grids with Schools as Community Hubs	Aden, Al-Hudaydah, Al-Mukalla (rural & peri-urban communities)	Solar mini grids for schools and surrounding communities (Outputs 3.1)	Deploy 50–200 kWp mini-grids to power schools, health posts, and households; provide energy for WASH, desalination, agro-processing, cold storage, fisheries, and micro-enterprises; establish community governance.	Expands energy access where grid extension is unfeasible, supports water security and essential services, strengthens value chains (palm dates, honey, sesame, fisheries), reduces GHG emissions, and mitigates rural climate migration.
Solar Productive Use for Water Security & Climate-Resilient Livelihoods	Aden, Al-Hudaydah, Al-Mukalla (urban & peri-urban, with rural outreach), Shabwah, Abyan	Solarization of productive-use technologies and LWSC water infrastructure (Outputs 3.1)	Install solar-powered agro-processing (dryers, mills, grinders), cold storage for crops & fisheries, and expand solar PV in LWSCs to power water pumping, desalination, treatment, and distribution. Support farmer cooperatives, women's groups, and fisheries associations in O&M.	Reduces post-harvest losses, strengthens food and water security, lowers LWSC operating costs, supports a fuel exit strategy in the water sector, displaces diesel, reduces GHG emissions, and diversifies livelihoods for women and youth.

Enabling Environment for Sustainable Deployment of DRE Interventions	National (with focus in Aden, Al-Hudaydah, Al-Mukalla)	Policy, regulatory, financial, and institutional measures to scale interventions (3.3 & 3.4)	Establish a de-risking framework for off-grid and mini-grids, develop business models, conduct feasibility studies, and strengthen institutions for O&M and governance. Promote PPPs, innovative financing, and capacity-building for communities, schools, and LWSCs.	Provides the institutional, technical, and financial foundation for scaling DRE systems, reduces investment risks, ensures long-term sustainability, and aligns with Yemen's coming NDC and national fuel exit strategy.

Project Strategy

CHAPTER 6

Project Strategy

6.1 Project Description

The project adopts a systemic nexus-based strategy to address Yemen's interlinked vulnerabilities in water, agriculture, ecosystems, and energy. It is designed to enhance the resilience of the most vulnerable groups: smallholder farmers whose livelihoods are undermined by water scarcity and land degradation; internally displaced persons (IDPs) who have settled in marginal areas with little access to safe water and energy; school students, both girls and boys, who face health and educational risks from extreme heat and inadequate infrastructure; households that spend up to one-fifth of their income on unsafe or trucked water; and local communities whose indigenous livelihoods such as honey production, date cultivation, sesame farming, and coastal fisheries are being eroded by salinity, desertification, and ecosystem collapse.

The starting point of the strategy is water, the scarcest and most contested resource in the targeted districts. In Shabwah, Abyan, Aden, and Al-Hudaydah, groundwater levels are falling by two to almost six meters per year. Salinity intrusion has rendered aquifers unfit for human and agricultural use, and untreated wastewater continues to contaminate shallow wells that serve as the primary supply for thousands of households, which threats increase during the extreme drought. These conditions not only threaten public health but also drive displacement and conflict over dwindling resources. The project will therefore invest in expanding non-conventional water sources, including rehabilitated wastewater treatment plants, decentralized greywater units, and compact reverse osmosis systems that will provide safe water in areas where total dissolved solids exceed 4,000–8,000 mg/L. These technical solutions will be complemented by rainwater harvesting structures, diversion barriers, and new storage tanks that capture scarce rainfall and channel it into aquifers, ensuring that households and farms have reliable buffers against prolonged droughts. In doing so, the project directly addresses the dual threats of scarcity and contamination, reducing reliance on unsafe wells and costly water trucking while creating a more resilient foundation for both domestic supply and productive agriculture.

Building on this foundation, the project strengthens agriculture, livelihoods, and ecosystems, which are collapsing under the combined pressures of recurrent droughts, flash floods, and land degradation. In Bayhan and Markha, traditional spate irrigation canals and diversion structures have been destroyed, leaving fertile soils exposed to destructive runoff, while advancing desertification in Rudhom has reduced date palm yields by nearly half. Sidr honey production, once a globally recognized livelihood, has fallen sharply in Nisab and Bayhan due to vegetation loss and drought. In Abyan, terrace systems in Sarar have collapsed, and the contamination of Lowder aquifers is increasing due to the limited efficiency of the sanitation systems. Despite the high quality of sesame and its oil in Abyan, and Lowder particularly, its production has declined by 25-40 % in the last five years due to the extreme drought, and land degradation.

The project responds by deploying climate-smart agriculture technologies that conserve water and protect crops from climatic extremes. Drip irrigation, mulching, and protective tunnels will reduce evaporation and

sustain yields even under rising temperatures, while village nurseries and climate-resilient greenhouses will provide seedlings of drought- and salinity- tolerant crops such as lemons, coffee, and vegetables. Ecosystem-based adaptation measures will restore rangelands through rotational grazing and soil conservation, rehabilitate spate irrigation canals, and reforest Sidr, and date palms to stabilize ecosystems and rebuild critical value chains. By restoring ecosystem services, stabilizing soils, and diversifying value chains such as sesame, dates, lemons, and honey, the project secures income streams for farmers, empowers women through processing and packaging enterprises, and provides youth with opportunities in greenhouse management and post-harvest services.

At the center of this strategy is renewable energy, which serves as the enabler that binds water, agriculture, and education into a coherent system of resilience. Diesel dependence in Yemen is both unsustainable and unaffordable, with fuel prices rising by 300–500 percent since 2015, forcing farmers and utilities to scale back pumping, desalination, and irrigation. The project will introduce decentralized solar photovoltaic systems to power water pumping, desalination, and productive uses such as milling, drying, and cold storage as well as the value chains of the cash crops, sesame dates and. In Aden (Albyriqah) Al-Hudaydah (Alkhoka), Nisab and Rodhum (Shabwah), solarized reverse osmosis plants of seawater and brackish (Nisab), will provide affordable, climate-resilient water services in areas facing deficits of tens of millions of cubic meters annually. . In rural and peri-urban areas, solar mini-grids anchored around schools will extend clean electricity beyond the classroom to surrounding communities, powering essential services and micro-enterprises. Within schools themselves, renewable energy will transform fragile facilities into climate-resilient learning hubs, providing reliable power for cooling, ICT, and WASH systems that protect students from extreme heat and ensure continuity of education. By directly linking solar deployment to both water security and livelihood diversification, the project ensures that renewable energy is not an isolated technology intervention but a cross-cutting driver of resilience, reducing greenhouse gas emissions while safeguarding food, water, and education systems.

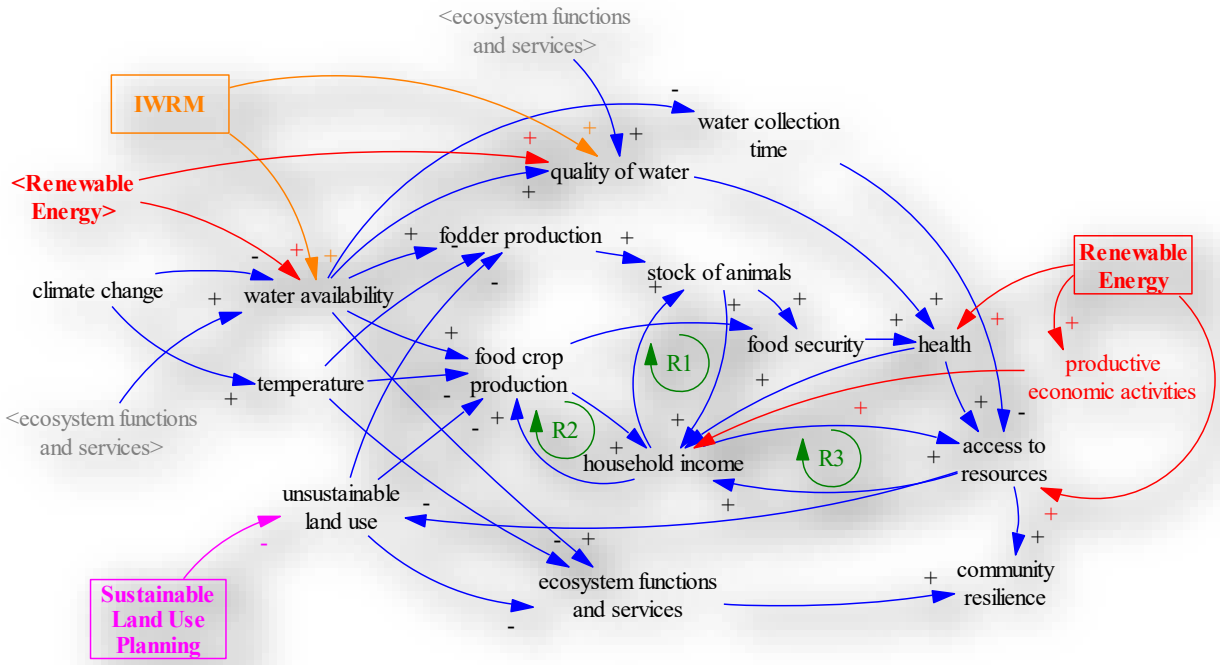


Figure 65:Project Systemic approach

As seen in figure X, taken together, the project embodies a systemic approach where each intervention reinforces the others: renewable energy sustains water services, water underpins, agriculture and ecosystems restore land productivity and biodiversity, public health and resilient livelihoods reduce pressures that drive climate-induced migration and conflict. By aligning these sectors into a single nexus-based framework, the project delivers transformational adaptation benefits to Yemen's most vulnerable communities while supporting the country's transition towards low-emission, climate-resilient development.

6.2 Theory of Change

Table 70: Component 1: Integrated Water Management

Component 1: Integrated Water Management
Outcome 1: Improved water availability, expanded use of non-conventional water resources and strengthened institutional and community capacity for integrated water resource management in selected districts.
Indicators: - Number of districts with operational IWRM and land-use plans integrating climate risks - Volume of additional safe water available from non-conventional sources (m^3/day).

- Number of institutions equipped with capacity building programmes
- % reduction in households reliance on trucked water in targeted districts.
- Number of direct beneficiaries with improved water security, disaggregated by sex.

Output 1.1 – Sustainable Integrated Water Resources Management (IWRM) Plans for Selected Districts

Water resources in the targeted districts of Shabwah and Abyan are under acute stress due to a combination of climatic variability, recurrent droughts, saline intrusion, and unregulated extraction. In Bayhan and Markha As Sufla (Shabwah), upstream diversions and deteriorated spate irrigation systems have reduced the flows reaching farmlands, while erosion and sedimentation frequently undermine traditional diversion structures. In Ahwar (Abyan), over-abstraction and insufficient recharge have left aquifers in rapid decline, while saline intrusion in the coastal zones further undermines water quality. In Sarar (Abyan**)**, prolonged drought and extremely limited natural recharge have created some of the harshest water scarcity conditions in the governorate, where households and farmers are increasingly reliant on costly trucking or unsafe shallow wells. This combination of scarcity and overuse illustrates why integrated planning is not optional but essential in Sarar, where water insecurity has reached critical levels. Without effective planning, water allocation is ad hoc and crisis-driven, intensifying competition between domestic, agricultural, and ecosystem needs.

Through this output, the project will support the development of comprehensive IWRM and spatial land-use plans (Output 2.1) at the four districts on watershed levels. These plans will be grounded in hydrological assessments, climate risk mapping, and water balance modeling. Technical work will include updating water demand projections for agriculture, domestic use, and ecosystems under climate scenarios; mapping priority recharge zones; and incorporating soil conservation and erosion control measures into land-use zoning. Special emphasis will be placed on integrating climate projections — for example, declining rainfall in Wadi Bayhan and projected salinity increases in Ahwar Delta— to ensure that allocation frameworks remain resilient under changing conditions.

By institutionalizing these plans, the project will provide clear, enforceable guidelines for water abstraction and allocation, reducing the current reliance on unsustainable shallow wells that are collapsing in districts like Sarar. Moreover, the IWRM frameworks will integrate nature-based solutions such as reforestation of degraded wadis, protection of riparian vegetation, and recharge barriers, which not only secure groundwater replenishment but also restore ecosystem services.

Output 1.2 – Human and Institutional Capacity Strengthening for the Adoption of IWRM

Even where plans and strategies exist, Yemen's water sector suffers from a chronic shortage of technical and institutional capacity, undermining the implementation of sustainable water management. In the targeted districts, this weakness is manifested in several ways. In Nisab (Shabwah) and Lawder (Abyan), illegal and unregulated well drilling continues without hydrogeological assessment, accelerating aquifer depletion. In Bayhan (Shabwah) and Sarar (Abyan), untreated wastewater is frequently used for irrigation during droughts, creating risks of soil degradation and public health crises. In Rudhom (Shabwah) and Al-

Mahfed (Abyan), saline water is being extracted and consumed without any monitoring or testing framework, exposing households to unsafe drinking water and further reducing agricultural viability. Community awareness of the long-term impacts of these practices is limited, while local water authorities and district councils lack the resources, expertise, and monitoring systems to enforce sustainable water management.

This output will therefore deliver a comprehensive, multi-tiered capacity-building program targeting both institutions and communities. At the institutional level, the project will provide technical support to the Environment Protection Authority (EPA), the National Water Resources Authority (NWRA), the Rural Water Authority (RWA), and district councils in the targeted areas. This support will include:

- Training and mentoring programs on integrated water resources management, with modules covering climate-adaptive water allocation, drought and flood risk management, safe wastewater reuse, saline water treatment, and ecosystem-based approaches.

- Development and deployment of monitoring and enforcement systems to track groundwater abstraction, regulate drilling, and prevent overuse. This will include provision of GIS-based monitoring platforms, hydrogeological mapping, and community-level reporting mechanisms.

- Establishment of water quality testing systems, including the provision of field kits, laboratory equipment, and training for technicians to regularly test for salinity, TDS, E. coli, and other contamination indicators. Results will be integrated into district-level water databases managed by NWRA and EPA.

- Operational support to relevant institutions, including equipment for field inspections, IT hardware for data management, and software for water accounting, and resources to ensure staff can conduct monitoring, enforcement, and reporting.

- Institutional coordination supports creating linkages between local authorities, EPA, NWRA, RWA, and district councils to ensure harmonized roles in implementing the IWRM plans developed under Output 1.1.

- Capacity-building for Water User Associations (WUAs), including training in water allocation, conflict resolution, sustainable irrigation practices, and record-keeping, to strengthen community-level governance and ensure local participation in IWRM implementation.

Output 1.3 – Increased Community Capacity for Water Capture, Harvesting, and Storage

The capacity to store and supply water is critically limited across the targeted districts of Shabwah and Abyan, leaving households and farms acutely vulnerable to prolonged droughts and seasonal scarcity. In Markha As Sufla, the city of Al-Hajr has only one operational storage tank serving nearly half of its population, forcing many families to rely on costly trucking at up to USD 20 for 6,000 liters, a burden

representing more than 10% of monthly household income. In Nisab (Shabwah), the absence of adequately sized reservoirs and cisterns means that communities cannot secure sufficient water reserves to meet domestic and agricultural demand during dry months, resulting in chronic shortages. In Bayhan (Shabwah), farmers and households experience acute seasonal scarcity as existing cisterns are inadequate to cover agricultural and domestic needs, pushing vulnerable groups toward unsafe shallow wells or expensive trucking. In Ahwar (Abyan), coastal households remain highly dependent on brackish wells and trucking because no reliable community-scale storage exists to ensure continuous supply. In Lawder (Abyan), water shortages are compounded by poor storage and conveyance infrastructure, with aquifer contamination from failing sanitation systems further underscoring the need for safe storage for domestic use. Finally, in Sarar (Abyan), while rainfall is limited and irregular, the absence of rainwater harvesting and diversion infrastructure prevents communities from capturing and retaining what little rainwater does fall, exacerbating extreme scarcity.

To address these challenges, this output will finance the rehabilitation and construction of storage and harvesting systems tailored to local needs. In Markha As Sufla, Nisab, Bayhan, Ahwar, and Lawder, the project will construct and expand elevated storage tanks, ground-level reservoirs, and communal cisterns designed to provide stable water supply for both household consumption and small-scale agriculture. In Sarar, the project will introduce rainwater harvesting units, runoff diversion structures, and small catchment cisterns to maximize the capture and productive use of seasonal rainfall. Across all districts, communities will be trained in the operation and maintenance of storage and harvesting systems, while awareness campaigns will promote efficient and equitable use of stored water.

Output 1.4 – Maximized Utilization of Wastewater, Greywater, and Brackish Water Treatment and Reuse

The over-reliance on contaminated and saline water sources has emerged as one of the most acute risks in the targeted governorates, particularly under worsening drought conditions. In Nisab (Shabwah), prolonged drought and falling groundwater tables have left households with few options for supply. With the local wastewater treatment plant non-functional, untreated sewage is discharged into wadis and infiltrates shallow aquifers, forcing communities to depend on unsafe water during dry months. In Lawder (Abyan), recurrent drought has intensified scarcity, while failing sanitation systems allow untreated effluent to contaminate local aquifers. During the driest periods, households have little alternative but to consume biologically polluted shallow well water, exposing communities to waterborne diseases. In Bayhan (Shabwah), drought has repeatedly reduced surface and groundwater availability, and in the absence of wastewater treatment, farmers and households resort to irrigating with untreated wastewater as a survival measure, despite the long-term health and soil risks. In Rudhom (Shabwah), where drought is compounded by salinity intrusion, communities rely on brackish water with TDS levels between 6,000–8,000 mg/L, far exceeding safe thresholds for agriculture and domestic use. Similar conditions are evident in Sarar, Hays, and Al-Khokhah, where drought and limited recharge exacerbate the reliance on contaminated or saline sources.

To respond to these drought-driven pressures, the project will deploy a portfolio of non-conventional water technologies tailored to district conditions. In Nisab and Lawder, wastewater treatment plants will be rehabilitated and upgraded, ensuring that effluent can be safely reused for agricultural purposes during dry periods, especially for the ecosystem restoration, and fodder cultivation (output 2.5). In Bayhan, Hays, and

Al-Khokhah, decentralized small-scale wastewater treatment plants (25–50 m³/day) will provide a safe and reliable alternative to the unsafe irrigation practices that become widespread during droughts. In Rudhom–Bir Ali, Nisab, Al-Khokhah, compact reverse osmosis (RO) units (200–400 m³/day) will treat brackish water, securing a dependable supply even when drought and saline intrusion render aquifers unusable. In Aden (Buraiqeh and Ras Amran), small-scale seawater/brackish RO units will be piloted to serve 3,000–4,000 residents, creating a replicable model for coastal drought-affected zones.

Table 71:Component 2: Agriculture, Livelihoods, Ecosystems, and Land Conservation

Component 2: Agriculture, Livelihoods, Ecosystems, and Land Conservation
Outcome 2: Enhanced climate-resilient agriculture, diversified livelihoods for vulnerable groups, sustainable land use, and improved irrigation infrastructure in selected districts.
Indicators - Number of spatial plans developed on district level - Hectares of degraded agricultural land under restoration - Hectares under sustainable land management practices (drip irrigation, mulching, tunnels). - % increase in crop yields (sorghum, millet, sesame, dates, lemons) in targeted districts. - Number of households benefiting from EbA-based livelihood diversification (honey, sesame oil, lemon, fisheries). - Number of women and youth engaged in climate-resilient value chains.

Output 2.1 – Improved Spatial and Land Use Planning through SEEA

The districts of Shabwah and Abyan face severe land degradation and unsustainable land use practices that undermine agricultural productivity and ecosystem stability. In Markha As Sufla and Bayhan (Shabwah), repeated flash floods erode wadi banks and strip fertile soils, while unregulated expansion of cultivation into fragile rangelands accelerates desertification. In Nisab (Shabwah), prolonged drought and groundwater depletion have severely constrained agricultural production, leaving households reliant on trucking and forcing farmers to expand into marginal, less-productive areas. In Rudhom (Shabwah), saline intrusion and declining recharge rates have degraded aquifers and reduced the viability of coastal agriculture, leading to abandonment of farmland and increased land degradation. In Ahwar (Abyan), salinity and drought stress have similarly reduced agricultural capacity and triggered desertification, with over 5,000 acres of farmland lost in one flood event. In Sarar (Abyan), the collapse of terrace systems has destabilized upland farming and diminished fodder availability for livestock, further eroding rural resilience, with 15–20 tons of topsoil lost per hectare annually and 40% of farmers abandoning terraces. These dynamics highlight the absence of systematic spatial planning, the failure to account for ecosystem services in local decision-making, and weak land governance under intensifying climate pressures.

To address these challenges, the project will introduce the System of Environmental Economic Accounting (SEEA) as a tool to integrate environmental and economic data into district-level land use planning. The SEEA approach will allow decision-makers to quantify the economic value of ecosystem services, assess trade-offs between competing land uses, and incorporate climate risks into long-term planning. Technical activities will include mapping land degradation hotspots using remote sensing and GIS; zoning agricultural, rangeland, and forest areas according to ecological sensitivity; valuing ecosystem services such as pollination, groundwater recharge, and soil stabilization; and applying climate risk models to identify zones vulnerable to floods, droughts, and salinity.

The application of SEEA will generate district-level land use and spatial plans that embed climate adaptation and ecosystem management. In Markha and Bayhan, SEEA will guide the rehabilitation of degraded irrigation canals and the allocation of spate flows to priority agricultural areas, ensuring sustainable water use while preventing erosion. In Nisab, SEEA will prioritize drought management, groundwater protection, and adaptive land allocation that reduces pressure on already stressed aquifers. In Rudhom, SEEA will help delineate salinity-affected areas and plan for adaptive land use that maintains agricultural productivity while restoring coastal ecosystems. In Sarar and Ahwar, SEEA will identify priority zones for reforestation, soil conservation, and fodder production to stabilize upland terraces.

By embedding SEEA in district planning and link it with IWRM planning under output 1.1, the project will ensure that water, land, and ecosystems are managed as a single system. This will reduce conflicts over land and water allocation, preserve critical ecosystem services such as soil fertility and biodiversity, and strengthen local governance capacity to manage resources sustainably. Over time, the integration of SEEA into district strategies will pave the way for replication and scaling of climate-resilient agricultural and ecosystem-based interventions across Yemen.

Output 2.2 – Tailored Capacity Building and Trainings for Climate-Resilient Livelihoods

In the targeted districts of Shabwah (Nisab, Bayhan, Markha, Rudhom) and Abyan (Lawder, Sarar, Ahwar, Al-Mahfed), low awareness and limited technical capacity among farmers, cooperatives, local authorities, and producer groups perpetuate unsustainable practices that heighten vulnerability to climate change. Farmers in Nisab and Bayhan continue to irrigate with untreated wastewater during droughts, exposing households to serious health risks and degrading soils. In Lawder and Sarar, the absence of knowledge on efficient irrigation and soil conservation contributes to declining yields, loss of soil fertility, and degradation of already fragile rangelands. In Rudhom and Ahwar, fisherfolk face saline intrusion and ecosystem degradation but lack access to adaptive practices and modern equipment that would sustain their coastal livelihoods. Across all districts, women and youth form a critical part of the agricultural labor force but remain largely excluded from training, decision-making, and access to resources, constraining the diffusion of adaptive practices.

This output will deliver comprehensive training and capacity-building programs tailored to the specific vulnerabilities of each district while also strengthening institutional actors at governorate and district levels. EPA branches, agricultural offices, and district councils will receive targeted training on spatial planning tools, application of the System of Environmental Economic Accounting (SEEA), ecosystem-based adaptation (EbA) approaches, and integration of climate risks into development planning. Agricultural

extension officers will be trained to support the uptake of climate-smart technologies such as drip irrigation, mulching, protective tunnels, and greenhouses, ensuring that these practices are not only introduced but embedded in local service delivery.

For communities, training will be delivered through farmer associations, cooperatives, CSOs, women's groups, and youth groups, covering EbA practices, sustainable livestock and fodder management, and the development of resilient value chains for sesame, dates, lemons, and honey. In Bayhan, Sidr honey producers will receive training in modern beekeeping and post-harvest handling. In Sarar, women's groups will be supported in coffee and lemon production, including nursery management and processing. In Rudhom and Ahwar, fisheries associations will be trained in adaptive fisheries management under saline intrusion and desertification pressures, and will be provided with basic equipment (nets, storage units, and small-scale processing tools) to reduce post-harvest losses and strengthen climate-resilient income streams.

By simultaneously building community-level skills and institutional capacity in EPA and agricultural offices, the project ensures that adaptive practices are mainstreamed into both governance frameworks and household-level livelihoods. This integrated approach ensures that investments in water, land, and ecosystem management are sustained and scaled. By targeting all districts of Shabwah and Abyan, the capacity-building program creates a consistent foundation for adaptive resource management across the two governorates, ensuring that climate-smart agriculture, fisheries, and EbA practices become embedded in both local governance and community livelihoods.

Output 2.3 – Rehabilitation and Protection of Irrigation Canals and Micro-Watersheds

Irrigation infrastructure in the project districts has been severely degraded by a combination of recurrent floods, prolonged droughts, the spread of invasive mesquite (Prosopis juliflora), and chronic lack of maintenance. In Bayhan and Markha (Shabwah), traditional spate irrigation canals and diversion weirs have collapsed, leaving farmland exposed to destructive runoff that erodes soils, reduces infiltration, and diminishes water availability for crops and livestock. In Ahwar, Lawder, and Al-Mahfed (Abyan), spate irrigation systems in wadis such as Fuaad and Hanan are deteriorating due to siltation, mesquite encroachment, and structural collapse, while in Sarar (Abyan), upland terrace systems have broken down, causing topsoil loss, reduced water retention, and declining agricultural yields. Across these districts, irrigation failure means that increasingly scarce water is poorly distributed, forcing farmers to abandon croplands or rely on costly water trucking, which is unsustainable under drought stress.

This output will finance the rehabilitation and reconstruction of irrigation infrastructure to restore and expand equitable access to water for agriculture and livestock. In Bayhan, Markha, and Nisab (Shabwah), traditional canals will be rehabilitated and reinforced with gabions and stone lining to reduce erosion and siltation, while new diversion structures will be built to ensure seasonal flows are captured and distributed efficiently. In Ahwar, Lawder, and Al-Mahfed (Abyan), degraded spate canals will be reconstructed and protected with check dams and sediment traps, stabilizing flows and extending irrigation to priority agricultural areas. In Sarar (Abyan), terrace rehabilitation will restore upland farming capacity, reducing uncontrolled runoff, enhancing soil fertility, and improving fodder availability for livestock.

By rehabilitating spate and terrace systems, these interventions address both drought and flood risks ensuring reliable water supply for crops and livestock during prolonged dry periods, while also preventing destructive erosion and waterlogging during extreme rainfall events. This is particularly critical in districts such as Bayhan and Markha, where soil erosion has already contributed to the loss of 30–35% of fertile topsoil, and in Sarar , where terrace and spate failures have reduced groundwater recharge and increased vulnerability to drought.

Output 2.4 – Deployment of Smart agriculture technologies to enhance agricultural productivity through innovative financial mechanism

Climate extremes have severely undermined crop production in the targeted districts. Prolonged droughts in Nisab and Rudhom (Shabwah) have reduced yields of sorghum and millet by up to 40%, while saline intrusion has damaged palm date and lemon groves in Ahwar and Al-Mahfed (Abyan). High temperatures and irregular rainfall shorten growing seasons and expose smallholders to repeated crop failures in all the targeted descrits, especially Lowder and Sarar.

To address these risks, this output will introduce a suite of climate-smart agriculture technologies. Drip irrigation systems will be installed to increase water productivity and reduce losses by 40–50%. Low-covered tunnels will be introduced in Rudhom, Ahwar, Markha, and Bayhan to protect vegetable crops from heat and irregular rainfall, increasing yields by 20–30%. Mulching and soil covering will be promoted to reduce evaporation and soil salinity, particularly in saline-affected areas of Rudhom and Ahwar. In Sarar and Al-Mahfed, climate-resilient greenhouses and nurseries will produce drought- and salinity-tolerant seedlings for lemons, coffee, and vegetables.

Output 2.5 – Improved Livelihood Diversification through Ecosystem-Based Adaptation (EbA) Approaches

Livelihood systems in Shabwah and Abyan are collapsing under the combined pressures of drought, salinity, and land degradation. In Bayhan and Nisab, production of Sidr honey has declined by 40–50% due to drought-damaged trees, eroding a critical source of rural income. In Lowder, Bayhan, and Ahwar, sesame cultivation has declined due to degraded lands and lack of processing facilities, while in Rudhom, advancing desertification and salinity have reduced date palm yields by 40–60%. In Sarar, coffee production has fallen dramatically under prolonged drought, threatening key value chains.

This output will strengthen climate-resilient livelihoods through EbA-based value chain development. In Lowder, Bayhan, and Ahwar, sesame cultivation will be rehabilitated, expanded, and linked to oil-extraction and packaging units. In Bayhan and Rudhom, date palm groves will be restored with improved irrigation, and post-harvest cold storage and packaging facilities will be introduced. In Sarar and Al-Mahfed, climate-resilient lemon expansion will be supported with drip irrigation and market linkages. In Bayhan and Nisab, Sidr tree reforestation will be combined with modern beekeeping and honey processing facilities. In Rudhom, the project will also promote mesquite recycling and valorization, converting invasive Prosopis juliflora biomass into charcoal briquettes, animal fodder supplements, or wood-based products. This approach will reduce the spread of mesquite on farmland and spate systems, while creating

new income streams for vulnerable households. Finally, in Lawder, Rudhom, Nisab, and Al-Mahfed, climate-resilient fodder farming will reduce pressure on degraded rangelands and provide reliable livestock feed.

Table 72:Component 3: Renewable Energy Deployment for Climate-Resilient Practices

Component 3: Renewable Energy Deployment for Climate-Resilient Practices
Outcome 3: Expanded access to decentralized renewable energy solutions and energy efficiency for climate-resilient livelihoods, water security, and education, supported by an enabling policy and investment environment.
Indicators - Installed renewable energy capacity in schools, LWSCs, and mini-grids (MW) - Annual GHG emissions mitigated (tCO_2e/year) - Number of schools with operational renewable-powered "Green School" systems - Number of LWSC facilities powered by solar systems under diesel exit strategy - People benefiting from renewable energy investments (disaggregated by sex) - Number of plans and pre-feasibility studies developed on district level

Output 3.1 – Established enabling environment for climate-resilient education systems at primary/secondary schools in selected districts through integrated renewable energy, energy efficiency, greening, and water services

Yemen's education system is acutely vulnerable to rising temperatures and chronic service disruptions. In Aden, Al-Hudaydah, and Al-Mukalla, classrooms routinely exceed safe thermal thresholds during heatwaves, while unreliable power deprives schools of lighting, ventilation/cooling, and digital learning. Many facilities also lack reliable access to safe water and sanitation due to energy constraints. This output will transform schools into Green Schools—climate-resilient learning hubs where renewable energy, energy efficiency (EE), green infrastructure, and basic services are integrated to safeguard student health and sustain learning.

The project will deploy off-grid solar PV systems (≈10–30 kWp per school) with battery storage to power classrooms, ICT labs, fans/ventilation, and school-based water services (pumps and point-of-use treatment). EE measures—LED lighting, high-efficiency appliances, smart load management—will reduce system size and operating costs. Greening measures (shade trees, pergolas, reflective surfaces, rainwater collection and storage where feasible) will improve microclimates and reduce indoor heat stress. School personnel, students, and community caretakers will receive operation, maintenance, and safety training, establishing local capacity for long-term sustainability and creating entry points for youth vocational pathways in RE/EE.

By integrating clean power, EE, greening, and reliable water services, Green Schools will lower heat exposure, reduce dehydration and illness, stabilize attendance and learning outcomes, and serve as accessible demonstration sites for climate-resilient design—models that can be replicated across the education sector.

Output 3.2 – Expansion of the access to climate-resilient energy technologies that support community-level water security, income-generating activities, and adaptive capacity to climate risks

Yemen's energy poverty has become a defining climate vulnerability. As extreme heatwaves intensify, schools, clinics, and households lack electricity for cooling, safe water pumping, sanitation, or even basic lighting. Diesel dependence has magnified this crisis: fuel prices have surged by 300–500% since 2015, crippling the ability of Local Water and Sanitation Corporations (LWSCs) to operate pumping and treatment facilities, while rural households and small businesses remain tied to costly generators or unsafe energy substitutes. This lack of reliable energy deepens exposure to climate shocks, erodes livelihoods, and prevents vulnerable groups from diversifying incomes or maintaining safe access to water and essential services.

To respond, this output introduces replicable mini-grid models that integrate renewable energy into schools, households, utilities, and productive sectors. These models form scalable pathways for climate-resilient electrification, ensuring that education, water security, and livelihoods are not only protected from climate risks but actively strengthened. By displacing diesel, they stabilize energy access, reduce greenhouse gas emissions, and establish renewable power as the enabling foundation of the project's nexus approach.

Mini-Grid Model 1: School-Anchored Community Hubs (Aden, Al-Mukalla, Al-Hudaydah)

This model establishes solar mini-grids (50–200 kW with storage or hybrid systems) anchored around schools, transforming them into dual-purpose resilience hubs. During school hours, they provide uninterrupted power for classrooms, cooling, ICT, and safe water services, protecting children from heat stress and ensuring quality education. Beyond the school gates, they extend electricity to households, small businesses, and community facilities, multiplying resilience benefits.

Key functions include:

- Reliable electricity for households, reducing reliance on kerosene and small diesel sets.
- Support for small businesses and microenterprises, enabling women and youth entrepreneurs to expand tailoring, food processing, ICT, and repair services.
- Street lighting and public safety improvements in underserved peri-urban neighborhoods.

- Continuity of essential services, including clinics, community centers, and small local water kiosks.

- Resilient schools as hubs, maintaining power for ICT, cooling, and water pumping while offering shelter and services during crises.

By rooting energy systems in schools, this model directly complements Output 3.1 (Green Schools), ensuring that investments in education infrastructure are leveraged to deliver wider community benefits and establish scalable blueprints for resilient electrification.

Mini-Grid Model 2: Utility-Scale Systems for water Services (Aden, Al-Mukalla, Al-Hudaydah)

This model expands decentralized renewable energy into urban and semi urban utilities, stabilizing the backbone of water and sanitation services populations.

- **LWSC operations:** Under the Ministry of Water and Environment's diesel exit strategy, solar retrofits will replace fossil fuel dependence at water pumping, sanitation, and distribution facilities managed by LWSCs in Aden, Al-Mukalla, and Al-Hudaydah. By shifting to renewable energy, utilities will achieve stable, low-emission, and affordable service delivery, reducing rationing, lowering O&M costs, and building resilience against volatile fuel markets. This transition anchors the broader national commitment to phase out diesel in the urban water and sanitation sector, while securing essential services for of thousands of climate-vulnerable residents.

- **Solar desalination Units:** Compact reverse osmosis (RO) plants (200–400 m^3/day) will be installed under Output 1.4 (non-conventional water solutions) in Rudhom and Nisab (Shabwah), Al-Khokhah (Al-Hudaydah), and Aden, where groundwater salinity (6,000–8,000 mg/L TDS) has rendered aquifers unusable. Within this energy model, the project will provide the solarization of these RO systems. This dual approach ensures that desalination infrastructure built under Output 1.4 becomes operationally sustainable, climate-resilient, and affordable. By securing safe, climate-proof water supplies under drought and salinity pressures, solarized desalination reduces household dependence on trucking or unsafe wells, while cutting greenhouse gas emissions and advancing Yemen's diesel exit strategy.

Through this model, renewable energy becomes the engine that sustains Yemen's most essential services, ensuring that cities remain habitable and adaptive under accelerating climate change.

Mini-Grid Model 3: Productive-Use Systems for Climate-Resilient Value Chains and livelihoods (All Targeted Governorates)

This model powers livelihood diversification and value chain development through renewable energy, ensuring that producers and SMEs can sustain incomes despite climate extremes.

- Sesame (Lawder, Bayhan, Ahwar): solar-powered oil extraction and packaging.

- Dates (Bayhan, Rudhom): solar drying, cold storage, and packaging facilities.

- Fisheries (Rudhom, Ahwar, Aden, Al-Hudaydah): solar ice-making and cold storage to reduce post-harvest losses.

By providing affordable and reliable power for processing, packaging, and storage, this model strengthens critical value chains, reduces waste, and creates opportunities for women and youth entrepreneurs. It directly reinforces Output 2.5 (livelihood diversification through ecosystem-based adaptation) by ensuring that EbA value chains are viable and scalable without reliance on costly diesel.

Together, the three models demonstrate how renewable energy is not a standalone intervention but the cross-cutting enabler of the project's integrated water–agriculture–energy–ecosystem nexus. By powering schools, utilities, and livelihoods, the mini-grid systems reduce climate vulnerability while laying the foundation for resilient, low-emission development across Yemen.

Output 3.3 – Decentralized Renewable Energy Investment (DREI) Studies

Despite the rapid, informal spread of solar PV across Yemen, large-scale deployment of decentralized renewable energy remains constrained by a lack of policy clarity, investment frameworks, and technical standards. The absence of systematic studies on mini-grids, solar home systems, and decentralized productive-use applications limits the ability of policymakers and financiers to design sustainable, de-risked business models.

This output will conduct Decentralized Renewable Energy Investment (DREI) studies to analyze the technical, financial, and regulatory requirements for scaling solar PV mini-grids, solar home systems, and hybrid productive-use models. The studies will cover site identification in priority districts such as Aden, Al-Hudaydah, and Al-Mukalla, assess demand profiles for schools, households, and water utilities, and evaluate financial instruments such as guarantees and blended finance.

By producing bankable knowledge products, the DREI studies will inform national energy strategies and guide both public and private investment. The climate rationale lies in enabling scaled replication of renewable energy systems that are essential for adaptation — particularly for water and education systems under increasing climatic stress.

Output 3.4 – Pre-Feasibility Studies, Business Models, and Investment Plans for Solar PV Technology

To move from pilot projects to large-scale deployment, Yemen urgently needs robust pre-feasibility studies and investment plans for solar PV systems. Currently, most projects are donor-driven, fragmented, and lack pathways for financial sustainability. Without bankable business models, scaling renewable energy remains a challenge, particularly in fragile and high-risk contexts.

This output will develop pre-feasibility studies, business models, and investment plans for solar PV in selected districts. Technical work will include resource assessments, system design options (off-grid, mini-grid, hybrid), cost-benefit analysis, and financial modeling. Business models will be tailored to schools, water utilities, and community mini-grids, balancing affordability with cost recovery. Investment plans will be prepared in partnership with local authorities, private sector actors, and international financiers, focusing on replication potential in Aden, Al-Hudaydah, and Al-Mukalla.

Table 73: Component 4: Knowledge Management, Capacity Building, and Replication

Component 4 – Knowledge Management, Capacity Building, and Replication
Outcome 4: Strengthened institutional, technical, and community capacities for knowledge generation, learning, and replication of integrated climate-resilient water-agriculture-energy systems, enabling scaling-up and policy mainstreaming across Yemen.
- Number of ministries, agencies, and local institutions with enhanced knowledge and data systems for climate adaptation. - Number of knowledge products, guidelines, and digital tools produced and disseminated. - Number of trained individuals (sex-disaggregated) applying new knowledge in planning and implementation. - Number of replication or upscaling initiatives leveraging project results. - Operational climate adaptation monitoring and evaluation system established and linked to the national ETF/MRV.

Output 4.1 – Mainstreaming Climate Knowledge and Awareness in Institutions, Communities, and Education Systems

Climate literacy remains extremely limited across Yemen's institutions and communities, constraining both adaptive planning and behavioral change. Under this output, the project will institutionalize climate education and awareness by embedding climate resilience principles into public education, sectoral training, and local governance frameworks. Key activities include:

- Development of curricula integrating climate change adaptation and mitigation into primary and secondary education, piloted in Aden, Al-Hudaydah, Al-Mukalla, Abyan, and Shabwah, with Training-of-Trainers programmes for 500 teachers (60 % women).
- Preparation of sector-specific guidebooks for water, agriculture, and energy ministries (MWE, MAIF, MEE) that translate climate science into actionable adaptation and mitigation measures, including gender and green-enterprise modules.
- Delivery of targeted training for at least 500 government staff and technical officers, focusing on sustainable resource management, solar O&M, data management, and gender mainstreaming in

adaptation planning. These efforts will create a continuous learning cycle that bridges education, policy, and community resilience.

Output 4.2 – Model Development and Awareness for Climate-Resilient Communities

Drawing on the results of Components 1–3, the project will identify and document district-level models of community-led resilience that demonstrate how renewable energy, water management, and ecosystem restoration jointly enhance livelihoods. Two gender-responsive community models will be developed—illustrating pathways such as:

- School-anchored energy and water hubs (e.g., Green Schools powering surrounding micro-enterprises and water kiosks).
- Integrated water-agriculture-energy systems that link solar pumping, climate-smart irrigation, and women-led processing enterprises.
- Knowledge products summarizing these models will be disseminated through awareness campaigns in all five governorates, reaching at least 1,000 participants. The underlying strategies and financial viability snapshots will inform the replication plan (Output 4.4).

Output 4.3 – Digitized Knowledge Management and Gender-Sensitive Learning Platform

Systematic knowledge capture and dissemination are central to sustaining project impacts. This output will establish a digital knowledge management system hosted by the Climate Change Unit (CCU) to collect, analyze, and share project data and lessons learned. Activities include:

- Design and operation of a project website and dashboard to share technical reports, gender-disaggregated datasets, and visual analytics.
- Preparation of annual Lessons Learned Reports (Years 1–4) and a Final Lessons Learned Report (Year 5) synthesizing results, challenges, and best practices.
- Development of a digital Quality Assurance Framework (QAF) and monitoring dashboard for distributed solar PV systems under Component 3, enabling third-party verification and adaptive management.

  These products will strengthen transparency, inform replication, and enhance Yemen's engagement in regional South-South exchanges on post-conflict climate resilience.

Output 4.4 – Replication and Scaling-Up of the Water–Agriculture–Livelihoods–Energy Nexus

To extend the project's transformational potential, this output will produce a Replication Plan and two bankable Concept Notes for submission to GCF and other climate-finance windows. Building on the integrated nexus models demonstrated in Shabwah, Abyan, Aden, and Al-Hudaydah, the replication framework will:

- Synthesize the most effective technical and institutional solutions for scaling up to new districts.

- Identify investment opportunities and co-financing pathways with international partners.
- Document gender-inclusive business models that incentivize private-sector participation in climate-resilient value chains. This will directly reinforce Yemen's national NDA and strengthen the country's readiness to mobilize additional adaptation and mitigation finance.

Output 4.5 – Operational Monitoring, Evaluation, and Enhanced Transparency Framework

A robust, transparent M&E and reporting system will be established to track adaptation outcomes and align with Article 13 of the Paris Agreement and the national MRV/ETF framework. Key activities include:

- Design of an online adaptation tracking module integrated into Yemen's national climate-finance platform, including at least four gender-disaggregated indicators.
- Capacity-building of institutional users across ministries and governorates—administrators, data providers, and quality-assurance teams—ensuring 40 % female participation.
- Regular feedback loops linking field results with national policy formulation and SDG indicator tracking.
  This system will enable data-driven decision-making, transparency in adaptation support received and implemented, and continuous improvement of Yemen's resilience strategies.

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