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REVIEW

Impact of the Sudan War on Biodiversity

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ABSTRACT

PURPOSE: The purpose of this paper is to illustrate how to conserve biodiversity in Sudan, given that biodiversity is important to conserve ecosystem resilience, improve human livelihoods and well-being, and to meet the United Nations Sustainable Development Goals (SDGs) by integrating biodiversity conservation efforts and engaging multidisciplinary stakeholders.

DESIGN: The paper reflects the multidisciplinary efforts directed at creating sustainable use of biodiversity and engaging ecologists and stakeholders in biodiversity conservation issues.

RESEARCH LIMITATIONS: This paper presents cited data based on research activities of sustainability-based efforts. It also discusses the authors' biodiversity surveys data of research projects formulated to monitor biodiversity in Sudan's semi-arid ecosystem.

FINDINGS: The potential interest in the Sudan biodiversity sustainability issue by many academicians, researchers, nongovernmental organisations (NGOs) and other relevant stakeholders has led to Sudan

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receiving multipurpose sustainability funds and building up smart scientific collaborations regionally and internationally. These funds are directed to perform biodiversity databases, write country reports on Sudan's biodiversity status, equitable benefits-sharing and sustainable use and conservation of biological resources and wildlife.

ORIGINALITY: This is an original paper based on the authors' research data and data cited from peer-reviewed journals interested in the biodiversity sustainability concept.

IMPLICATIONS: This paper could inspire biodiversity interested communities to tackle biodiversity use and conservation according to the suitable SDGs.

KEYWORDS: *Sudan; Biodiversity; Sudan War; SDGs; Sustainability; Conservation; Strategies.*

INTRODUCTION

This paper concentrates on utilising Sudan's biodiversity in a sustainable way towards achieving the UN's Agenda 2030 Sustainable Development Goals (SDGs). As biodiversity is an important component in the ecosystem, it needs specific attention in order to achieve these goals. The scientific community and biodiversity-interested institutions should collaborate in achieving the SDGs in order to conserve biodiversity. Sudan's biodiversity is threatened by human interventions, unsustainable use of biological resources and natural habitat fragmentation. War and armed conflicts have added to the increasing biodiversity degradation rate, which in turn is intensified by climate change factors: Sudan has been classified as one of the most affected climate change countries. Unless biodiversity conservation and climate change mitigation efforts are synchronised, significant un-reversible deterioration of the biological resource could reach a disastrous magnitude.

Biodiversity Concept

The Convention on Biological Diversity (CBD, 1992) defines biodiversity as the variety of living organisms from all ecosystems together with terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they may be a component. This concept diverts diversity within species, between species and across ecosystems, representing the genetic make-up of plants, animals, micro-organisms and the complexity of ecosystems. The Food and Agriculture Organisation (FAO, 2016) reported that biological resources include forestry, range, aromatic and medicinal plants, micro-organisms, and animal resources and wildlife. Within the SDG framework, biodiversity is related to several SDGs, e.g., SDG 15, which aims to "protect, restore and promote sustainable use

of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (Figure 1).

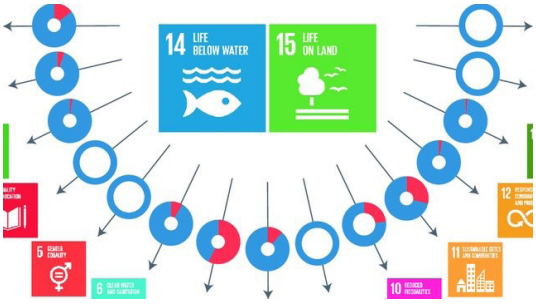

Figure 1: Contribution of biodiversity to SDGs.
Blue = co-benefits, Red = trade-offs.
Source: Obrecht *et al.*, 2021

Biodiversity Benefits

The World Health Organization (WHO, 2025) reported that biodiversity presents direct benefits in achieving food security, provision of wood, firewood, traditional and complementary medicinal products and providing income-generating tools, particularly for rural poor communities (Figure 2). Therefore, biodiversity encourages economic development and sustains poverty reduction, coinciding with SDG 1, prevents hunger (SDG 2) and improves health (SDG 3). Samal and Dash (2023) showed that biodiversity secures indirect benefits via sustaining ecosystem functioning and regulation of air, soil and water sources, revealing that biodiversity provides areas for training and education and generates opportunities for ecotourism (Keck *et al*., 2025). The World Bank recommended the utilisation of biodiversity data in conservation and further research. Additionally, the World Bank has involved biodiversity issue in its11th annual Measuring Development (Measure Dev) Conference, entitled "Biodiversity on Land and at Sea" in 2025. The conference is mandated to develop and increase obtainable data, to pioneer tools for appraising the fundamental biodiversity conservation policies. This looked to gather different stakeholders interested in biodiversity conservation and its enrolment into sustainable development strategies. Furthermore, institutions interested in biodiversity have started to concentrate on different ecological problems that impose direct and indirect effects on humans and ecosystems and have gained global attention, such as climate change effects and mitigation, desertification, land and soil degradations.

Historically, biodiversity studies in Sudan were directed at the evaluation of the ecological importance of biota and to build up the field collection capacities of researchers. Recently, research projects were designed and rationalised to document biota and identify conservation needs in addition to considering the socio-economic values of the available biota. Other studies care

about endogenous knowledge of the local communities and conduct informal seminars and group meetings to improve the environmental know-how of the communities. Moreover, some Sudanese universities and research centres rationalised their research projects to cope with the United Nations' SDGs such as the sustainable use of biodiversity in Sudan's semi-arid ecosystem formulated by the National Centre for Research (NCR) in collaboration with the Agricultural Research Corporation (ARC) and some Sudanese universities, especially those located within the semi-arid ecosystem, e.g., University of Kordofan, Sudan. The research institutions and universities in Sudan are those that are expected to undertake research activities and studies that could be devoted to achieving relevant SDGs within their purview.

Figure 2: Eco-wheel image shows natural resources provided by biodiversity, the benefits and beneficiaries, and drivers of change

Source: Pickard *et al*., 2015

Biodiversity Threats

Carter and Rosa (2023) illustrated that biodiversity is threatened by human interventions and climate change. Shaftel *et al*. (2020) referred to climate change as a long-term shift in temperatures and weather conditions due to natural or human impact factors. The natural factors could be due to changes in the sun's activity or large volcanic eruptions, whereas human interference could be seen in burning fossil fuels for energy provision. Shilenje (2014) described climate change as a key driver of the biodiversity threat since it affects the atmosphere over comparable time periods. Martay *et al*. (2017) examined the impact of climate change on biodiversity in Great Britain. They came to conclude that climate change has drastically altered ecosystems and biological communities' phenology and abundance, especially when considering key biological groups. Many authors and human organisations have studied the impact of climate change on biodiversity. The World Health Organisation (WHO) (2023) outlined that climate change has significant negative impacts

on ecosystems, leading to habitat destruction. Likewise, the International Union for Conservation of Nature (IUCN) (2025) explains that climate change affects oceans' biota by increasing water acidity and rising sea levels and thus creating an unsuitable living habitat for organisms, resulting in biological species losses. Peng *et al*. (2023) delineated that the complicated balance of ecosystems altered by climate change is reflected in increasing temperatures, shifting weather conditions and a rise in CO2 levels. They added that plant species have optimal temperature values to flourish, beyond which a significant decrease in plant population could occur. Aslam *et al*. (2023) reported that climate change is also altering precipitation patterns, leading to drought cycles and eventual floods. Since plants are adapted to certain moisture regimes, these extreme fluctuations might subject them to water stress that disturbs vegetative growth and reproduction. Magiri *et al*. (2021) indicated that climate change has a profound effect on animals by increasing their susceptibility to vector and non-vector pathogens, heat stress and metabolic disturbance that lead to decreasing animal species diversity. Climate change causes and effects have received significant global attention and consideration, especially in the UN's SDGs that designated SDG 13 to take urgent action to combat climate change and its impacts. Therefore, mitigating climate change's impact can reduce its threatening effects on biodiversity.

Arifin *et al*. (2024) refers to human intervention in the environment as an "ecocide process". Human involvement in threatening biodiversity includes the introduction of exotic and alien species, habitat fragmentation and unsustainable use of biological resources. Obrecht *et al*. (2021) elaborated that identifying the interactions between the SDGs and sustainable use of biodiversity is one of the most potent levers to achieve more than one SDG.

Monitoring and Documenting Sudan's Biodiversity

Despite the exhorted efforts to achieve the UN's SDGs in monitoring Sudan's biodiversity, limited success has been gained in long-term biodiversity monitoring. This could be ascribed to the country's political instability that prevents field surveys, in addition to the lack of logistics and workforce. The Higher Council for Environment and Natural Resources (HCENR) (2015) outlined that biodiversity research and monitoring began in Sudan before independence, focusing on agricultural and forest flora, domestic animals and insects of medical and veterinary importance (e.g., Figures 3 and 4). Later, Siddig *et al*. (2018) reviewed Sudan's biodiversity in relation to a sustainable development approach. In addition to reflecting biodiversity threats and conservation efforts, they described the country's ecosystems and the importance of biological resources to human livelihoods,. Recently, a number of integrated research studies and reports were conducted on sustaining Sudan's biodiversity, threats and conservation efforts (e.g., FAO, 2020; Basheir *et al*., 2021; Abdellatif *et al*., 2023; Abdellatif *et al*., 2024).

Figure 3: Examples of Sudan flora and fauna Figure 4 Examples of Sudan insects
Source: Photos taken by author Abdellatif, 2022; NCR, 2021

Sudan's biodiversity under war conditions

Conserving biodiversity is one of the objectives to which SDG 15 is devoted. According to Meaza *et al*. (2024), war causes environmental pollution and natural habitat degradation with consequent biodiversity loss. Siddig (2014) mentioned that, historically, Sudan has suffered civil wars and armed conflicts that extend over 60 years. He added that these conflicts have led to serious degradation of biological resources to such an extent that some plant and animal species have become extinct. Hanson (2018) affirmed that biodiversity is not only affected during war itself, but also during the pre- and post-war times. Hassanein (2024) stated that on 15 April 2023, armed conflicts occurred between the Sudanese Armed Forces and the Rapid Support Forces in different Sudanese states. He added that the most affected states were Khartoum, Gezira, Central and West Darfur, North, South and West Kordofan. Since then, more than 5 million people have been internally displaced, 1.4 million have emigrated, and more than 12,000 individuals have been killed.

Tryjanowski and Węgiel (2025) mentioned that the Sudan war is similar to the conflicts that happened in Syria and Iraq in its ecological and socio-economic impacts. They added that these wars have threatened biodiversity at critical magnitudes (Figures 5 and 6). El Tahir *et al*. (2025) showed that the Sudan war has caused significant challenges to biodiversity conservation and achieving food security and reducing poverty, which coincide with the objectives of more than one SDG. These challenges have increased rapidly over time and have been intensified by Sudan's vulnerability to climate change effects and imposing targets on biodiversity conservation and climate change mitigation.

The United Nations Refugee Commissioner (UNHCR) (2025) reported that the Sudan war elicited direct and indirect ecological and socio-economic effects that were intensified by climate change. Jaspars and Oette (2023) emphasised that human displacement in Sudan intensified degradation of biodiversity by human misuse of the biological resources for subsistence and these impacts are intensified by climate change that needs urgent combat action (SDG 13). Air and drone strikes during the war induced fires and burning plant covers. Displaced individuals exhorted potential pressure and misuse of biological resources such as over-cutting of trees for fuel or the construction of shelters. Yasin *et al*. (2023) confirmed that human-intensive deforestation activities for charcoal and fuel wood production have potential ecological impacts, including land degradation, desertification and soil fertility loss. Since SDG 15 is mandated to protect, restore and promote sustainable use of ecosystems, sustainably manage forests, combat desertification, and halt and reverse land; efforts should be directed to reduce deforestation and provide alternative energy sources to prevent plant cutting.

Figure 5: Removal of plant cover for fuel

Figure 6: Burning plant cover for fuel

Source: Photos taken by author Abdellah, 2025

Siddig (2014) reviewed that the Sudan war affected animal welfare; this refers to the alleviation of cruelty and animal suffering. Animal killings, over-hunting deaths due to the absence of veterinary services and fodder shortages in the Sudan conflict zones are indicted by Atar (2024). The Sudan war has affected natural museums and gene banks. These museums contain cultural and natural heritage in the form of collections and associated knowledge, learning and research programmes that can support the SDGs. A Svalbard Global Seed Vault (2025) report stated that the

Sudan gene bank contains the essential varieties of sorghum and pearl millet in addition to 16,739 seed accessions of 69 crops in long-term storage in the gene bank, and 359 accessions of banana and 179 accessions of date palm. The value of this gene bank is to reduce hunger by keeping the essential Sudanese food varsities (i.e., SDG 2). The Sudan war negatively affected wildlife and protected areas. The conservation of migratory species and their habitats is essential for achieving the SDGs, since wildlife is part of all ecosystems and present direct and indirect benefits for Man and the ecosystem.

Importance of conserving Sudan's biodiversity

Sudan's biodiversity has considerable socio-economic and ecological significance, manifested in ecosystem services that are essential for human welfare. Pickard *et al*. (2015) generalised that biodiversity services to the ecosystem include, amongst others, climate change mitigation where forest plants serve to sequester carbon dioxide, triggering biochemical processes such as organic matter decomposition and nutrient release and cycling. It is believed that ecosystems with higher biodiversity tend to be more resilient and contribute to ecosystem function regulations. Additionally, biodiversity presents a source of genetic diversity of flora and fauna that results in increased agricultural productivity and therefore consistent food security.

Salmi *et al*. (2023) illustrated that biodiversity provides raw materials for various industrial sectors, providing resources for livelihoods. Biodiversity encourages ecological knowledge that facilitates recognising biological processes, evolution, and other environmental inter- and intra-relationships. Biodiversity conservation is needed to guarantee a sustainable and flourishing future for both the ecosystem and human societies; it can also be optimised by implementing the appropriate SDG. Some SDGs are devoted to biodiversity conservation and based on identified commitments and regulations. In this sense, Sudan has a political commitment to biodiversity components and ecosystems as high development priorities. Likewise, Sudan ratified the Convention on Biological Diversity (CBD) in 1995, with its three applications of conservation, sustainable use and equitable share of biological resources. CBD calls upon all parties to develop and update National Biodiversity Plans for conservation and sustainable use of biological resources in a timely manner. The objectives of these conservation plans include calls for education, research, capacity building and awareness-raising on biodiversity values and conservation (HCENR, 2020).

The Higher Council for Environment and Natural Resources (HCENR, 2015) previously confirmed that Sudan has formulated a National Biodiversity Strategy and Action Plan (NBSAP, 2015-2020) as a key planning tool for biodiversity conservation and the fulfilment of international commitments. This strategy considered the national policies and comprehensive plans that prioritised biodiversity conservation needs in terms of sustainable use and equitable benefits sharing. This strategy plan has to be implemented in collaboration and partnership with all relevant stakeholders.

Also, biodiversity research and conservation methods should be prioritised according to the degree of biodiversity loss and degradation, empower community knowledge and awareness of biodiversity values. Furthermore, enrolment of local communities, especially in the areas vulnerable to climate change, impacts the restoration of the biological resources via growing plant seedlings, herding animals and protecting bio-reserves. Rist *et al*. (2024) reported hypotheses that correlate biodiversity and war, especially those considering environmental ethics, international safety and threats. These authors clarified that such hypotheses suggested providing data on pre- and post-war biodiversity status, and determining the quantitative and qualitative impact of war on biodiversity in order to direct scientific research to fulfil the gaps in the impact of war on biodiversity data. Also, adopting conservation polices to rank war and conflicts impacts studies as a crucial threat to biodiversity conservation and sustainability.

SUDAN'S BIODIVERSITY SUSTAINABILITY EFFORTS

The biological resources of Sudan have recently been degraded due to unsustainable use and other human interventions, which are increased by climate change effects. Consequent natural habitat fragmentation and biodiversity loss occurred. Such a situation necessitates urgent and significant action to reduce these degradations, and to protect and prevent the extinction of threatened species. It is a challenging issue for ecologists, researchers and other stakeholders to mitigate these impacts via the recognition of one or more of the Agenda 2030's 17 SDGs.

Sudan has implemented multidisciplinary and multi-institutional biodiversity research and conservation projects mandated to monitor and document the country's biological resources, measure the spatiotemporal changes, and discover the direction of these changes. The data obtained from these projects were analysed and interpreted to recommend appropriate conservation methods and to encourage the utilisation of the available biological resources in a sustainable way that guarantees benefits for future generations. Mahmoud (2020) reported examples of research projects mandated for the environmental impact assessment of biodiversity in Sudan. His findings confirmed that sustainable uses of both aquatic and terrestrial biota added significantly to their conservation efforts.

Example of Sudan's recent efforts in biodiversity sustainability

The United Nations Environment Programme (UNEP) (2025) reported that, with the European Union (EU), they had launched a sustainability-based initiative in Sudan that aimed to enhance food security for communities in and around Sudan's Dinder National Park. It is hoped that this initiative improves climate resilience, and contributes to durable peace and social stability. Dinder National Park is one of Africa's oldest protected areas - established in 1935 - and is home to a range of important ecosystems and biodiversity. The ecological role of this park involves regulating

water flow for two of the River Nile tributaries, namely the Dinder and Rahad rivers. Provision of water assists the subsistence agriculture practiced by the local inhabitants and the livelihoods of the people displaced from the conflict zones. The settlement of these displaced people serves to reduce their ecological impact, such as their contribution to natural habitat fragmentation and biodiversity loss due to devegetation and over-hunting. Implementation of this project is a climate-smart agro-ecological practice to strengthen climate resilience and reduce the conflicts over biological resources, in other words, to enable the share of benefits among the local community. These aims will be achieved by improving access to climate information, implementing early action strategies to safeguard food security, and ensuring inclusive, equitable and sustainable access to natural resources.

Achieving Sustainable Development Goals under War Conditions

Garcês and Pires (2025) reported that war and armed conflicts usually affect the environment and humans; integrated work that leads to decreasing conflict impacts and developing the affected population is therefore required, in addition to attracting internal and external efforts as part of mitigating war impacts. Kumar (2018) showed that there is an increased political instability worldwide and peace and stability are crucial for achieving sustainable development targets. Wang *et al*. (2024) cited the specific impacts of armed conflict on achieving the 17 SDGs in affected countries between 2000 and 2021. Their findings indicate that more than half of the SDGs' achievements slowed by over 5% in these countries. These findings may lead conflict zone countries to prioritise key SDGs to be implemented. Recently, armed conflicts and violence have led to increased poverty, with levels expected to rise by 2030. It is evident that obtaining peace is a prerequisite to achieve the SDGs.

Why do we Need to Protect Sudan's Biodiversity after War?

War and armed conflicts can result in biodiversity loss due to human displacement to safe zones. Historically, the continuous violence in Sudan poses a real threat to the country's biological resources, wildlife and bio-reserves and altered conservation efforts. The Sudan war directly affected biodiversity by human misuse of biological resources, e.g., burning plant cover, deforestation, and over-hunting for domestic uses. It has resulted in environmental pollution of different types, i.e., thermal, eco and chemical pollution. These environmental hazards have led to the degradation of biological resources, either by direct elimination from the ecosystem or by altering their natural habitat and making them unsuitable for living and proliferation of wildlife. Keeping healthy ecosystems and sustainably managed resources could reduce the impact of war and armed conflict, and it has become a vital issue to direct our efforts to the full implementation of the SDGs. To protect Sudan's biodiversity, we must keep the ecosystem functioning and thus provide necessary

human livelihood needs and secure food. In order to protect Sudan's biodiversity, researchers, academicians and other stakeholders should make a road map starting by evaluating the impact of the war on biodiversity and recommending time-scheduled activities to restore plant cover, improve the range of flora, encouraging most affected communities to participate in these activities with the enrolment of youth and women sectors.

Key components to conserve Sudan's biodiversity

Environmental education, training and raising awareness among the different stockholders on the biodiversity value, sustainable use and maintenance, in addition to strengthening of the legislation and policies are considered as key factors in future biodiversity conservation efforts. Moreover, enrolment of the local communities in every conservation activity will lead to the achievement of successful conservation regulations and efforts.

CONCLUSIONS

Recently, most of the research activities have been rationalised to clarify the relationship between biodiversity and the SDGs. These activities revealed that conservation of biodiversity is a pillar in achieving SDGs. In Sudan, biodiversity conservation is essential for the continuing survival of endemic biological species and the protection of their natural habitats and ecosystems. Such conservation efforts contribute to economic growth and thus improve livelihoods. Hassan *et al*. (2023) discussed the environmental hazards, including climate change effects on Sudan flora diversity with an emphasis on date palm farming, which is essential for achieving food security and poverty alleviation. They recommended the application of appropriate agricultural technology, improving farmers' awareness of suitable crop growing practices; marketing has significantly improved the pre- and post-harvesting parameters of the crop product. In contrast, Yasin *et al*. (2024) argued that Sudan's forests improve livelihoods, sustain food security, provide fodder and shelter, and serve vital ecological functions. They added that human misuse of forest resources has resulted in undesirable consequences, such as food shortages, land and water resource degradation, and biodiversity loss. These authors recommend the adoption of suitable conservation methods is needed to keep ecosystems functioning. El Tahir *et al*. (2010) mentioned that biodiversity conservation efforts should be prioritised to protect the endangered species and then implementation of conservation plans.

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