Project Update: January 2022

Introduction

Overgrazing, intensive browsing and illegal harvesting are among the major causes of species diversity declines, rangeland degradation and deforestation in different parts of the world (Derebe and Girma 2020; Kochare *et al.* 2018; Luginbuhl *et al.* 2010). Moreover, in Africa, particularly the Sahel and Sub-Saharan countries, overgrazing has significantly contributed to the reduction in vegetation cover and woody resources (Alzubair and Hamdan 2020; Kikoti *et al*. 2015), biodiversity loss and habitat fragmentation (Hasoba *et al.* 2020; John *et al*. 2020), and increased soil erosion and invasive species invention in most frequently grazed and browsed sites (Gebru *et al*. 2019; Kingazi *et al.* 2020; Mohammed *et al*. 2021). However, information is lacking about the effects of grazing and browsing on the seedlings and saplings of *B. aegyptiaca* in Sudan, especially in rangelands and natural reserves.

Balanites aegyptiaca is an evergreen and multiuse tree species native to the Sahelian region (Figure 1), with diversified food, feed, medicinal, and ecological uses (Hassanin *et al*. 2018; Idrissa *et al*. 2018; Mohammed *et al*. 2021). The species is widely distributed in Sudan at different population densities, varying from semi-desert areas in the north to the heavily rained areas in the southern and eastern regions (Elfeel and Warrag 2011; Fadl 2015; Mohammed *et al*. 2021). Its fruits and seed kernel oil play a significant source of income for the local communities, while its twigs, shoots and fresh leaves are good forage for livestock and wild browsers (Adam *et al*. 2013; Idrissa *et al*. 2018; Younis *et al*. 2018). Furthermore, extracts from the species bark, roots and fruits had proved their medicinal potential as antibiotic, antioxidant, antimicrobial, and antifungal compounds (Abdallah *et al*. 2012; Alansari and Al-thobaiti 2021; Singh *et al*. 2017). Despite its manifold uses, little is known on the vulnerability of *B. aegyptiaca* seedlings and saplings to livestock grazing and browsing, and how different livestock species influence their survival and recruitment. Therefore, this study aimed to explore the responses of *B. aegyptiaca* seedlings and saplings to livestock grazing and browsing towards the conservation and sustainable management of the species in Sudan.

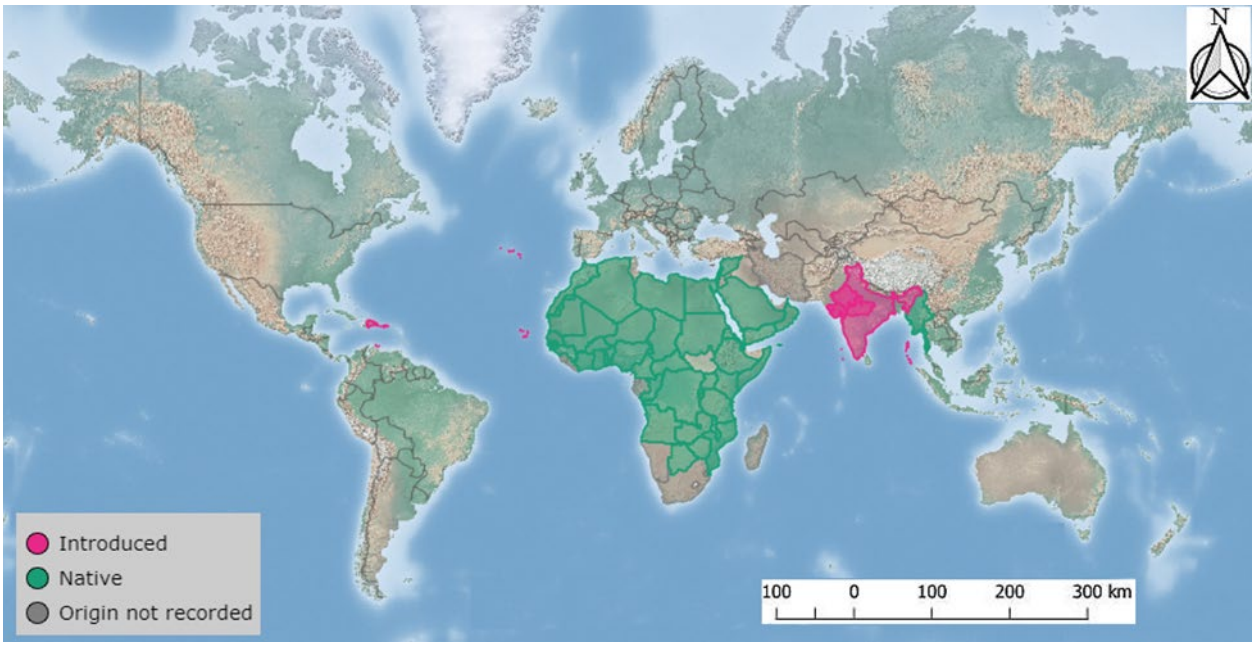

Figure 1: Global distribution of *B. aegyptiaca*. The green areas show where *B. aegyptiaca* is native, while the red-purple areas indicate sites where the species has been introduced. Moreover, the grey areas illustrate where the species has never been recorded (Centre for Agriculture and Bioscience International [CABI], 2021).

Reconnaissance Survey

The survey aimed to identify:

1. The areas dominated by *Balanites aegyptiaca* for further assessment and measurement.
2. The frequently/intensively, moderately, and rarely/none grazed/browsed sites.
3. The various grazing/browsing animals in the study area and their intensities.
4. The potential villages for socio-economic questionnaires and interviews.

To accomplish this reconnaissance survey, we used a random sampling technique where 450 circular sample plots were measured that covered the three zones of the reserve (150 samples in each zone, plate 1). The sample plot area was 1 ha, and the cruised three zones of Dinder Biosphere Reserve were transition, buffer, and core zone. Moreover, for the socio-economic study, nine villages have been selected for further detailed questionnaires and interviews based on the local's income generation sources, types of dominant livestock, and the common tree species.

Plate 1: Shows, instruments and tools used during reconnaissance survey, as well as some photos for the surveyed sites.

Stratification of the Study Area

The stratification process depended on the main type of livestock species found in the stratum during the reconnaissance survey and fieldwork activities, and the income sources for the locals. For seedling and sapling assessment (regeneration), we established a sum of 200 squared sample plots with an area of 5 x 5 m^2, that randomly distributed in four stratified sites as 50 samples per site across the study area (Figure 2). Site 1 (GOA) is mainly browsed by goats, while site 2 (CAT) and site 3 (CAM) are browsed by cattle and camels, respectively (Plate 2). Site 4 (CON) was free of livestock, and we used it as a control site. Direct observation of the livestock type, presence of their dung, their annual trespassing records from the administration of DBR (2019, 2018, 2017, 2016, and 2015), and the published literature (Mahgoub 2014; Mohammed and Hashim 2015; Mohammed *et al.* 2021), were used to determine the main livestock browser in each site across the study area. Moreover, for adult tree assessment, we inventoried a total of 100 rectangular sample plots with an area of 25 x 40 m^2 across the disturbed and non-disturbed sites of Dinder Biosphere Reserve (Figure 3).

Assessment of *Balanites aegyptiaca* Seedlings and Saplings

We recorded the number of *B. aegyptiaca* seedlings and saplings in each 5 x 5 m^2 sample plot and classified them into unbrowsed (healthy), browsed (affected), recovered, or dead in all study sites. For the purpose of this study, we defined seedlings as young plants with < 3 cm in stem diameter (Lempesi *et al*. 2017; Lopez-Sanchez *et al*. 2014; Papadopoulos *et al*. 2017) and usually < 1.5 m in height (Mohammed *et al*. 2021), while saplings were 3 to 7 cm in stem diameter (Dibaba *et al*. 2020; Kikoti *et al*. 2015) and up to 2.5 m in height (Gebeyehu *et al*. 2019; Hanief *et al*. 2016) (Plate 3).

A seedling or sapling was considered to be browsed if any of its branches or leaves had been damaged by an animal bite (Ahmed 2005; Kikoti *et al*. 2015; Mohammed *et al*. 2021). For each browsed seedling or sapling, we recorded the number of branches, which had recovered or died from browsing, as well as the browsing height. Recovery state was based on the presence of fresh leaves and new shoots in seedlings or saplings after being browsed by animals (Derebe and Girma 2020; Mohammed *et al*. 2021) (Plate 4). We also measured the diameter and height of all counted seedlings and saplings by using vernier caliper and Suunto clinometer, respectively.

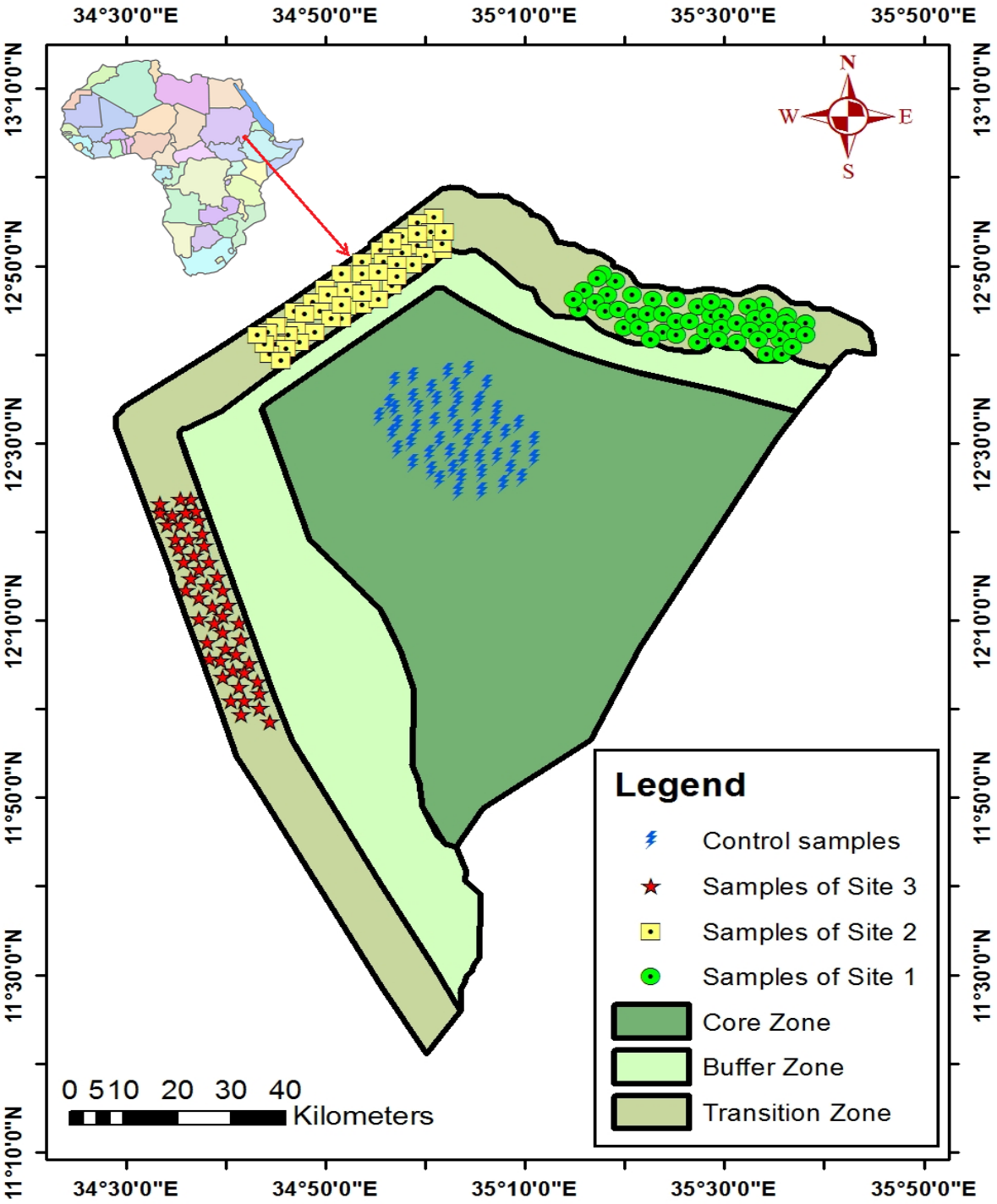

Figure 2: The stratified sites of Dinder Biosphere Reserve. Green circles, yellow squares, pink stars and blue bolts indicate the sample-plots of the four sampled sites, i.e., GOA (site browsed predominantly by goats), CAT (site browsed predominantly by cattle), CAM (site browsed predominantly by camels) and CON (control without livestock browsers), respectively.

Plate 2: Trespassed livestock observed and identified in the study area during the reconnaissance survey.

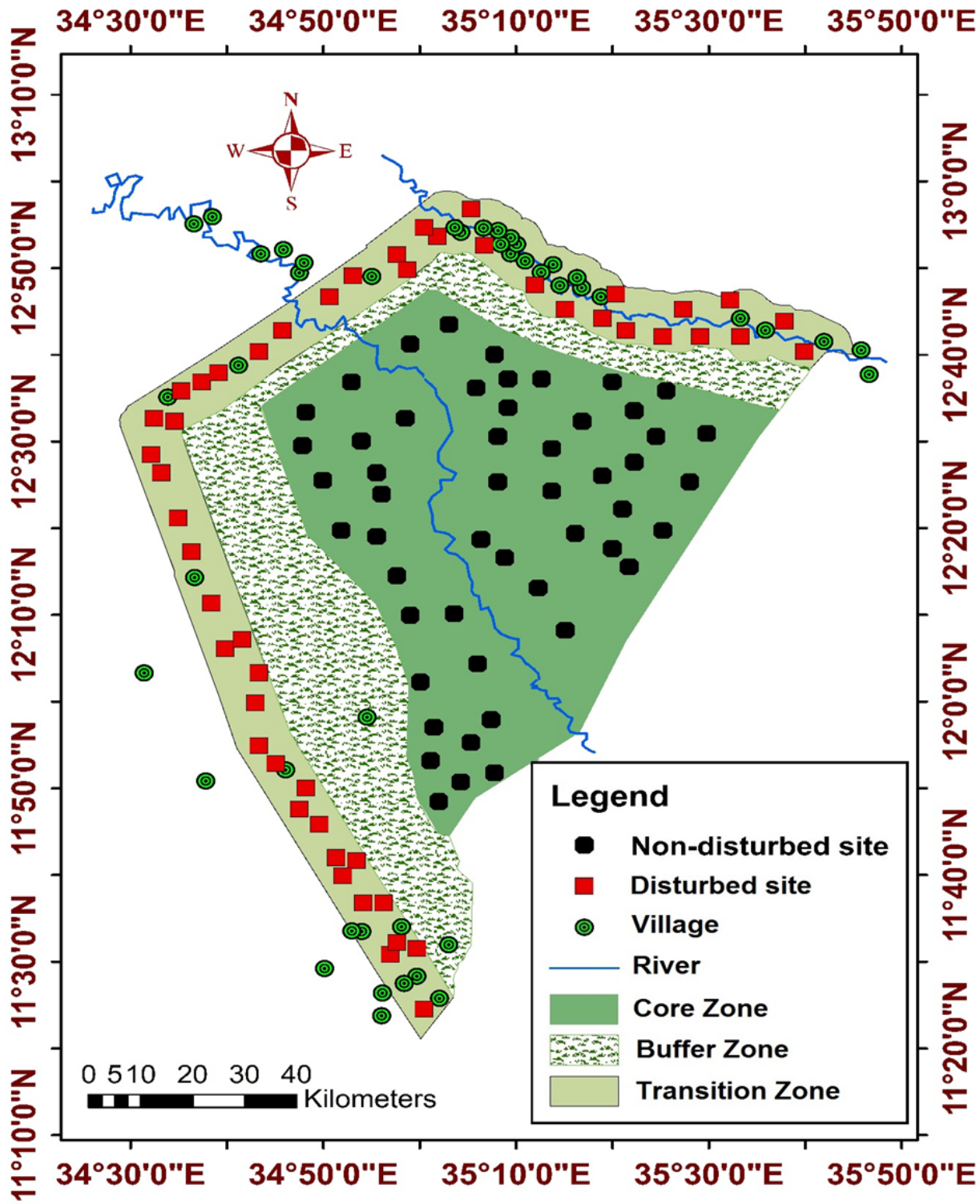

Figure 3: The map of the study area, with the sampling locations in the non-disturbed and disturbed sites of Dinder Biosphere Reserve, where we assessed the dendrometric parameters of *B. aegyptiaca* adult trees (Diameter, Height, Crown width, and Crown height).

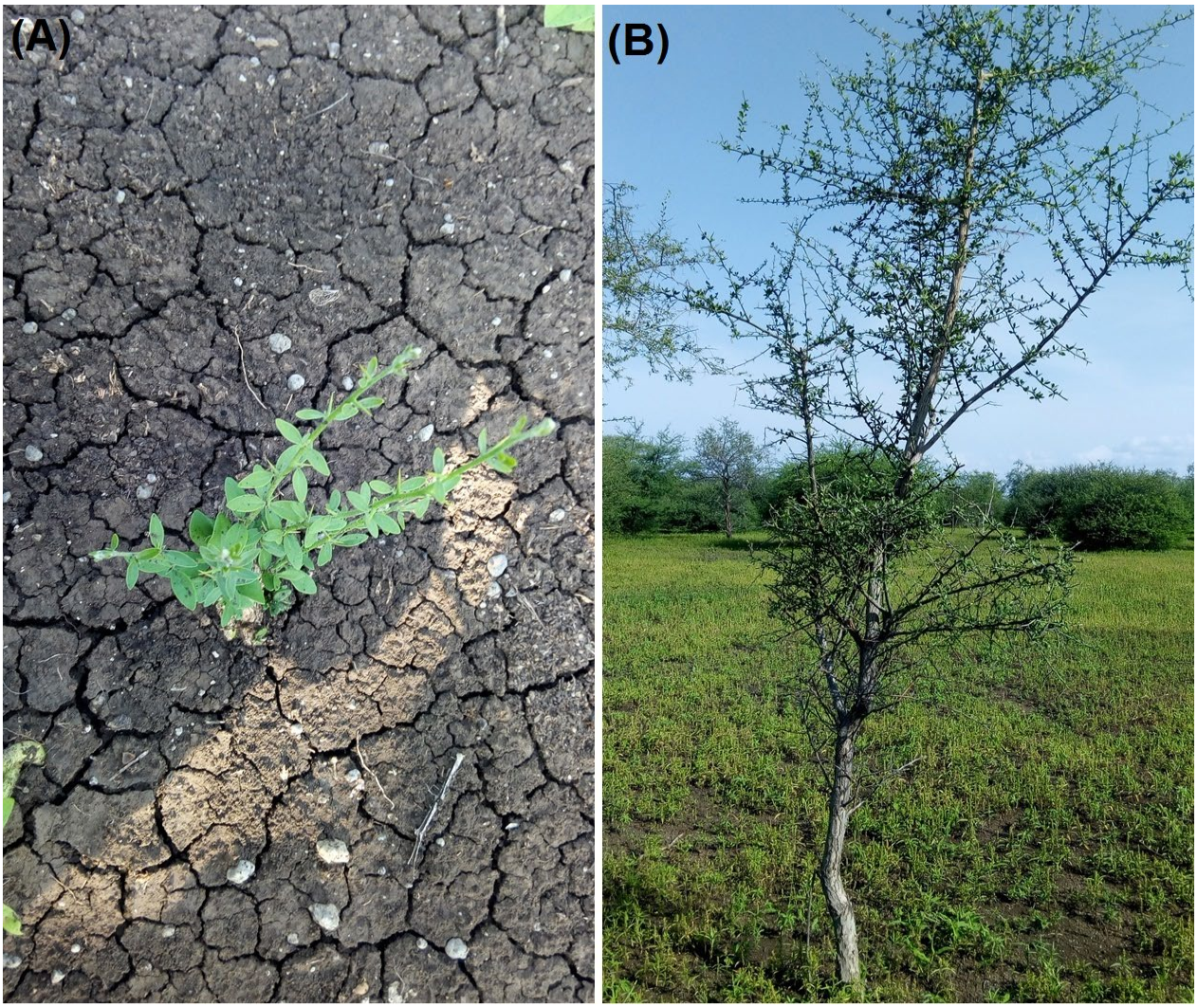

Plate 3: Displays; (A) healthy (unbrowsed) *B. aegyptiaca* seedling and (B) Healthy (unbrowsed) *B. aegyptiaca* sapling assessed in Dinder Biosphere Reserve.

Assessment of the Adult *Balanites aegyptiaca* Trees

To assess the stocking density of adult *B. aegyptiaca* trees, four dendrometric parameters (height, DBH, crown width, and crown height) were measured in the sampled sites (Figure 3 and Plate 5). Tree DBH was measured using ordinary caliper (65 cm) for the small and juvenile trees and tape (5 m) for the largest (Ibrahim and Hassan 2015). Suunto hypsometer and Spiegel relaskope were used for total tree height (H) and crown height (CH) measurements, respectively (Ibrahim *et al*. 2015). In addition to that, tree crown width (CW) was measured by using a 50 m distance measuring tape at eight directions radiating from the tree base and vertically towards the edges of the tree crown and stand canopy (Ibrahim *et al*. 2014; Mohammed *et al*. 2021).

Plate 4: Illustrates; (A) recovered *B. aegyptiaca* seedling, and (B) recovered *B. aegyptiaca* sapling measured in Dinder Biosphere Reserve

Awareness-raising and the socio-economic study

Depending on the reconnaissance survey findings, nine villages have been selected for questionnaire and key informant interviews. We interviewed the chiefs of selected villages (N = 9), government officers (forests, rangelands, and wildlife authority officers; N = 15), and non-governmental organisation representatives (N = 5). Moreover, the questionnaires cover 270 participants as 30 individuals per village. The selected villages were Um-Elkheir, Nor-Elmadeina, Elkhairat, Korwash, Gari, Um-Bagara, Gadaf, Amri, and Mokla (Figure 4, plate 6). Awareness raising activities and conservation training covered all interviewed and questionnaire participants and students from these villages as well as the patrolling guards of the reserve.

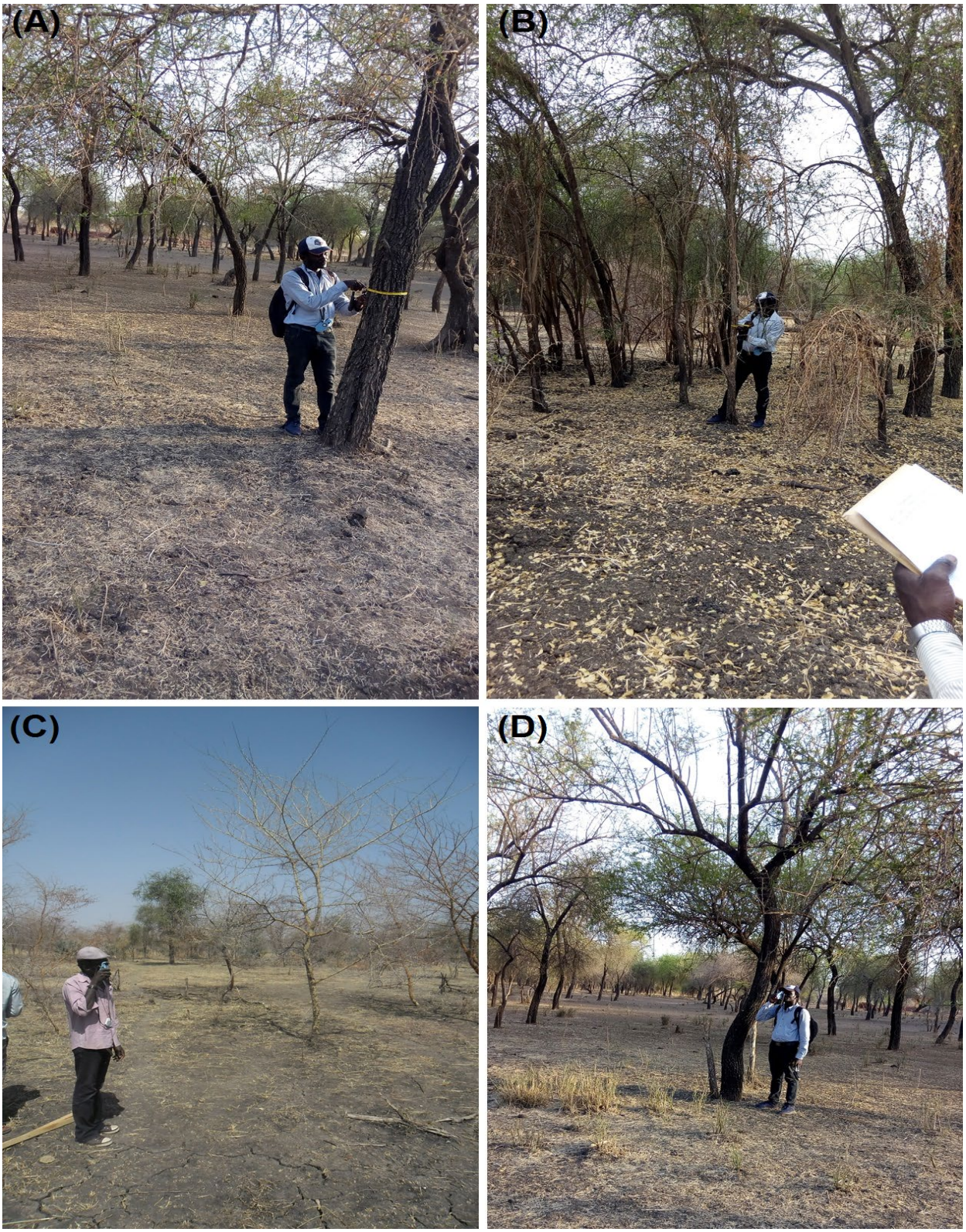

Plate 5: Shows the measurement of small and large tree diameter, height, and basal area/ha as (A), (B), (C), and (D), respectively.

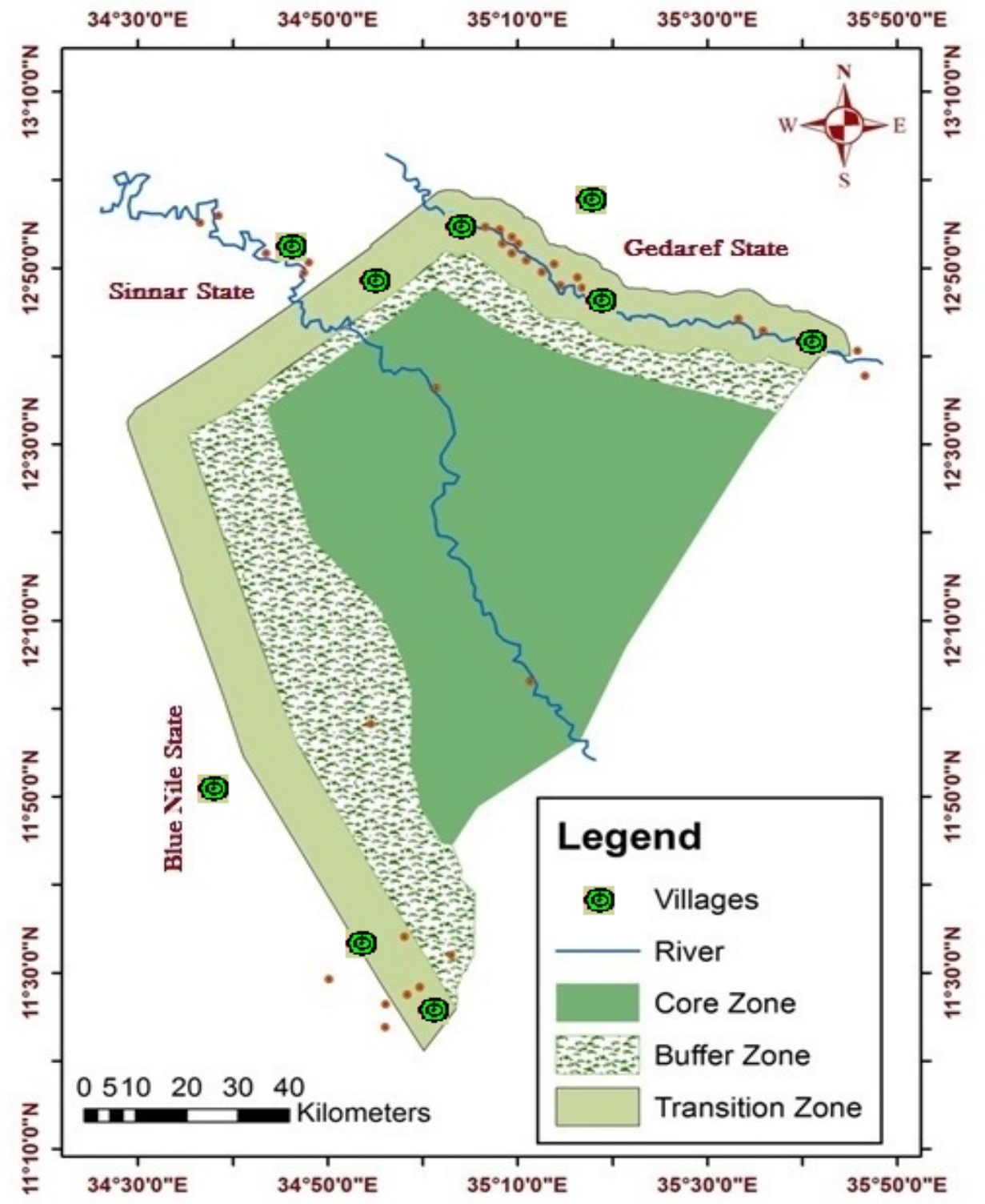

Figure 4: Map of the study area illustrating the three zones of Dinder Biosphere Reserve and the location of selected villages for questionnaire, key informant interviews, and awareness-raising.

Plate 6: Some photos for the interview activities and fruits of *Balanites aegyptiaca* in the reserve.

Output

A. Published research articles:

1. Livestock browsing threatens the survival of *Balanites aegyptiaca* seedlings and saplings in Dinder Biosphere Reserve, Sudan (2021). Journal of Sustainable Forestry (Taylor & Francis). https://www.tandfonline.com/doi/abs/10.1080/10549811.2021.1935279
2. Illegal harvesting threatens fruit production and seedling recruitment of *Balanites aegyptiaca* in Dinder Biosphere Reserve, Sudan (2021). Global Ecology and Conservation (Elsevier). https://www.sciencedirect.com/science/article/pii/S2351989421002821?via%3Dihub

B. Poster:

- **Poster Title:** Anthropogenic pressure on tree species diversity, composition, and growth of *Balanites aegyptiaca* in Dinder Biosphere Reserve, Sudan.
- **Conference Theme:** Agro-ecology as a pathway towards sustainable food system.

- **Location of the conference:** The Nelson Mandela African Institution of Sciences and Technology (NM-AIST), Arusha, Tanzania.
- **Date:** 13th October 2020.

Challenges

- COVID- 19: The project activities were stopped for 6 months in 2020 due to a complete lockdown in Sudan because of COVID-19.
- The unstable political situation in the country delayed the socio-economic study for three months in 2021.

Way Forward

- Planning for a feedback meeting with the local communities living within and around the biosphere reserve.
- Drafting a third manuscript.
- Preparing the final report.

Anthropogenic Pressure on Tree species Diversity, Composition, and Growth of *Balanites aegyptiaca* in Dinder Biosphere Reserve, Sudan

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Introduction

❖Biosphere reserves constitute a massive stock of biodiversity and perform a principal role towards the satisfaction of various needs for the local communities worldwide. However, the recent and rapidly increasing over-exploitation and other human disturbances may strongly degrade the dynamics of these resources and interrupt their sustainability.

❖Therefore, the current study analyzed the influence of anthropogenic pressure, in particular illegal harvesting and livestock browsing, on the tree species diversity, composition, and growth of *B. aegyptiaca* in the Dinder Biosphere Reserve, Sudan. We hypothesized that disturbed sites in the DBR had lower tree species diversity and regeneration than the non-disturbed sites, and that only a few tree species will dominate.

Materials and Methods

- The study take place in DBR (Fig. 1).
- Stratified sampling design was used and study was divided into non-disturbed and disturbed sites based on anthropogenic activities.
- After identifying all tree species within the sites, we classified them into adults, saplings, and seedlings.
- Parameters measured during data collection encompass diameter, height, crown width and density.
- Importance Value Index (IVI), Simpson's diversity index (ID), Principal Component Analysis, and two-way anova were used for data analysis.

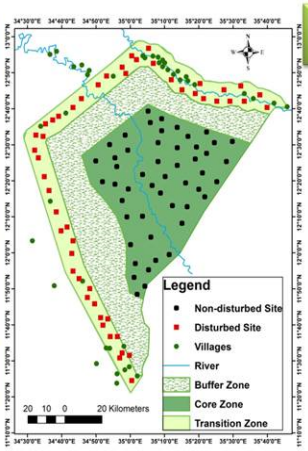

Fig. 1: Study area

Conclusion

- ❑ Lower species richness in disturbed sites compared to non-disturbed sites.
- ❑ Vigorous natural regeneration in non-disturbed sites.
- ❑ *Balanites aegyptiaca* is first top dominant tree species in the non-disturbed and second dominant in the disturbed sites.
- ❑ Acacia seyal invaded most disturbed sites in the study area.
- ❑ Monitoring and awareness-raising are urgently needed for sustainability.
- ❑ Introduction of community forests to restore the degraded areas.

Results

- ➢ Species diversity and regeneration in non-disturbed sites were double to that of disturbed sites (Fig. 2).
- ➢ More juvenile and codominant trees in non-disturbed sites compared to disturbed ones (Fig. 3).
- ➢ Lower density in disturbed sites in comparison to non-disturbed ones.

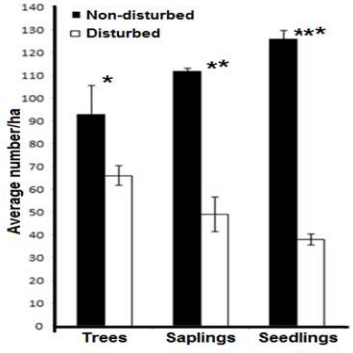

Fig. 2: Density of trees, saplings, and seedlings in DBR

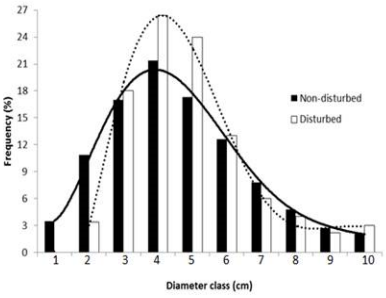

Fig. 3: Weibull distribution for diameter classes

Poster 1: Anthropogenic pressure on tree species diversity, composition, and growth of *Balanites aegyptiaca* in Dinder Biosphere Reserve, Sudan. The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania (2020).

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